ANNUAL CONVENTION, HOTEL ASTOR, NEW YORK, N. Y., MAY 19-23, 1924

VOL. 11 NO. 2 MARCH, 1924

PROCEEDINGS 44TH YEAR

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

PUBLISHED IN JANUARY, MARCH, MAY, JULY, SEPTEMBER AND NOVEMBER

BY THE

AMERICAN WATER WORKS ASSOCIATION

AT MOUNT ROYAL AND GUILFORD AVENUES, BALTIMORE, MD.

SECRETARY'S OFFICE, 170 BROADWAY, NEW YORK
EDITOR'S OFFICE, 16 WEST SARATOGA STREET, BALTIMORE, MARYLAND

Subscription price, $7.00 per annum

Entered as second class matter April 10, 1914, at the Post Office at Baltimore, Md., under the act of August 24, 1912.
Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917; authorized August 6, 1918

Made in United States of America

JOURNAL
OF THE
AMERICAN WATER WORKS ASSOCIATION

The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings
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VOL. 11 MARCH, 1924 No. 2

SELECTION OF AUXILIARIES FOR STEAM-OPERATED PUMPING STATIONS[1]

BY F. G. CUNNINGHAM[2]

Nowadays the logical selection of condenser and boiler-room auxiliaries in steam-operated pumping stations requires consideration of quite a number of alternate types of apparatus, whereas formerly nearly everything was driven by reciprocating steam-engines. All of the older types are still available in improved forms. In addition there are steam-jet ejectors and hydraulic air-pumps for producing vacuum, centrifugal pumps for an increasing variety of applications, and water-turbines, steam-turbines and electric motors for driving centrifugal pumps, stokers and fans. The tendency is toward the use of simple and reliable auxiliaries that require little attendance. More attention is paid to securing an economical heat-balance in the station and to keeping oil out of the condensate. The thermal economy in using steam extracted from the main units for feed-water or other heating is recognized. The increasing use of steam at high pressures and temperatures has militated to some extent

[1] This paper has been prepared under the direction of the Council to furnish useful imformation and to call forth discussion on pumping station betterments. Personnel of Committee No. 7, Pumping Station Betterments: Leonard A. Day, Chairman, St. Louis, Mo.; J. N. Chester, Pittsburgh, Pa.; F. G. Cunningham, Memphis, Tenn.; L. R. Howson, Chicago, Ill.; L. A. Quayle, Cleveland, Ohio.

[2] With Fuller and McClintock, New York, N. Y.

against the use of auxiliary steam-turbines and steam-engines, which ordinarily are less adapted than the main units to these steam conditions.

Water-turbines, operated by water taken from the pressure mains and returned to the suction system, in many cases are proving advantageous for driving auxiliaries. They may be used economically for driving even secondary pumps of large capacity and low head, where such pumps are located near large high-head pumps. In an application of this sort at Memphis, it was found that the steam indirectly used by water-driven secondary pumps, each of some 50 brake horsepower, would be less than half the requirement of the most efficient alternate driving device.

In stations where the make-up water has corrosive or scale-forming tendencies it may be advisable to pass it through a distilling plant. Where such a plant is provided, its design and the selection of other station auxiliaries must be considered together if a suitable heat balance is to be obtained. In fact, all of the equipment in any station should be considered collectively as well as individually, in order to secure the best over-all economy and a consistent and sufficient degree of reliability throughout.

What is desired of the station equipment, taken as a whole, is the highest general average when rated upon the following qualities:

Reliability	Ease of maintenance
Economy	Sustained efficiency
Simplicity	Adaptability to varying conditions
Accessibility	Durability

METHODS OF DRIVING AUXILIARIES

Depending upon their application, auxiliaries may be driven by one or more of the following methods: steam engines, steam turbines, steam ejectors, water turbines, electric motors and by direct attachment to another unit. The first three of these might be called direct methods, since their reliability depends upon no external factor except the maintenance of steam pressure. The last three methods are indirect, in that they require both the maintenance of steam pressure and the continued functioning of some other pieces of apparatus.

In general steam-driven auxiliaries have no superior in reliability. A station fully equipped with them has always within itself the means for resuming operations after a shut-down, provided only that steam pressure be maintained. Auxiliaries driven by indirect

methods should be used only where the reliability of their sources of energy is safeguarded sufficiently for the purpose. This point is occasionally overlooked, as in one case where two uniflow-engine-generators were equipped with electrically driven circulating pumps, making it quite difficult to start the generators after accidents had necessitated cutting off power from the main switchboard.

Besides being reliable, steam-engines and steam-turbines have the advantages of being capable of wide variations in speed and susceptible to automatic means of speed regulation. Their disadvantages are in the matters of maintenance, repair, lubrication and attendance in which the engines are inferior to the turbines and in which both are inferior to electric motors and water-turbines. A further objection to engines is that they introduce cylinder oil into the condensate, when their exhaust steam is used for feed water heating. Since auxiliaries are usually somewhat neglected, the steam consumption of small engines or turbines is apt to become excessive after a few years use and may become double the original rate.

Next to steam, water under pressure is usually the most reliable source of energy in the station and may be appropriately used for driving many auxiliaries, particularly those for condensers. Due to the fact that the main pumps usually operate at high efficiencies, water-driven auxiliaries frequently are far more economical in power than those of any other type. They are also simple, easy to maintain and are more apt to sustain their efficiences than small engines or turbines. They are capable of speed variation to a moderate extent. Where their use is contemplated, investigation should be made to see that the head and speed conditions are suitable.

The suitability of electrically-driven auxiliaries in a given case depends upon the reliability and economy with which power is generated. Usually it is necessary to have two or more generators in a station to provide reliable plant lighting. If these are of an economical type the power may be used to drive some of the auxiliaries. No matter what precautions are taken to secure reliability there is always the possibility of interruptions in electrical power circuits due to fuses blowing out and similar causes. Electrically-driven apparatus, therefore, should not be used where absolute continuity of service is required, as for condenser auxiliaries of high service pumps delivering water directly into the mains. Where interruptions of five or ten minutes duration can be tolerated they may be made sufficiently reliable.

While station generators usually are essential, they often must operate with an extremely poor load factor, the load varying from a few lights to a combination of motors for the shop, crane and conveying equipment. In such cases the addition to the load of a few small motor-driven auxiliaries operating almost continuously may greatly improve the load factor and not materially increase the steam consumption of the generator. For driving small station generators having poor load factors nothing is as economical as uniflow-engines, which may be designed to have an almost flat water-rate curve from one-third load to full load.

Auxiliaries driven by attachments to the main units are seldom used except as condenser auxiliaries. In such service their reliability is equal to that of the main unit served and is sufficient. One disadvantage of attached condenser auxiliaries which may be more or less important is that the vacum cannot be established before the unit is in operation.

RELIABILITY

The reliability of a water supply system should be such that no single failure in any part could impair its ability to maintain full domestic and fire service. If the system includes storage reservoirs or basins, the need for continuous operation of the station is lessened to some extent, at least as regards that part of the equipment devoted to filling the reservoirs. Usually there is considerable storage provided between low-lift and high-lift stages of pumping, as in filter plant installations, and no storage is provided beyond the high service pumps. In such cases, types of auxiliaries might be used appropriately in the low-service pumping that would be unsuitable for the high-service work. The presence or absence of reservoirs, therefore, have a direct effect upon the selection and arrangement of auxiliaries in the station.

In planning to make all parts of the station equipment sufficiently reliable it is difficult to keep out inconsistencies, but the more serious ones at least can be avoided. For example, if there is only one reserve main pumping unit in a station beyond the number necessary to maintain maximum service, it should be made impossible for any single breakdown of a valve, run of pipe or piece of equipment to result in two or more main pumps being shut down. Water pressure (unless from gravity storage) and electric current should not be depended upon to such an extent that the station could not be

brought into operation without them. One good test for reliability is to assume the station to be entirely shut down and no pressure in the mains and then consider what steps would be necessary to bring it into operation again. While this is a rather severe criterion, it usually will be found that the deficiencies discovered in this way may be remedied by providing a few simple emergency devices or connections.

COMPARING POWER REQUIREMENTS OF AUXILIARIES

In considering various types of auxiliaries their power requirement cannot be compared directly upon a proportional basis, because the sources of steam used in feed water or other heating must be taken into account. The first step is to determine the average value of a pound of steam, which will be the sum of the fixed charges and operating costs of the steam-generating plant divided by the average station evaporation. In the next step two general cases must be considered, namely:

Case 1. Stations in which it is not practicable to extract steam from the principal condensing units at pressures slightly above atmospheric and to use such steam for feed water or other heating. In such stations the steam consumption of steam-driven, non-condensing, auxiliaries is of little consequence as long as all of the exhaust steam may be utilized for heating. All excess exhaust steam and all steam used directly or indirectly by condensing auxiliaries, auxiliaries driven by water bled from the mains, and auxiliaries attached to the main units, should be charged with the full value of the steam used.

Case 2. Stations in which extraction of steam from the principal condensing units is practicable. All extracted steam used for heating should be charged only as the amount of steam that must be added at the throttles of the extraction units to replace the amount extracted. This may be anywhere from 20 to 70 per cent of the amount extracted. All steam required by steam-driven non-condensing auxiliaries and utilized for heating may be regarded as diminishing in the same amount the quantity of steam that may be extracted from the main units, and should be charged with the value of the work that this amount of steam could have done had it been passed through the main units and extracted. The amount thus charged may be anywhere from 30 to 80 per cent of that actually used. Excess exhaust steam and steam used by all auxiliaries except steam-driven non-condensing auxiliaries should be charged at full value.

In both the above cases, when auxiliaries are driven by water-power or electricity or when they are attached to the main units, they should bear their proportionate share of the fixed charges on the engine room equipment serving them, in addition to the charges described above.

HEAT BALANCE

When the exhaust steam from all of the non-condensing auxiliaries, the steam bled from main units, the drips from jackets and steam pipes, and other steam or hot water from similar sources are collected and used for feed water and other essential heating, and when the total heat from such sources is just sufficient for the purpose, a heat balance is secured. In the absence of an economizer and distilling apparatus the desirable feed temperature is of course about 210 degrees.

While success in securing a heat balance is essential, it does not necessarily follow that the greatest practicable thermal economy has been obtained. The only ultimate criterion for this is to minimize the total station evaporation, which will vary with different methods of securing a balance. In the first place, the initial temperature of the condensate should be kept as high as the vacuum temperature will permit, either by suitable condenser design or by the use of vacuum exhaust heaters.

Where steam extraction is impracticable steam-driven non-condensing auxiliaries will give the highest thermal economy, as long as there is no waste or excess of exhaust steam. In such cases it is better to have too little than too much exhaust steam, on account of the tendency for such auxiliaries to deteriorate in efficiency. The deficiency can be supplied with live steam.

Where steam extraction is practicable, the steam extracted and the steam required directly or indirectly to drive auxiliaries should be rated arbitrarily after the method described in the preceding section. The heat balance which will then give the greatest thermal economy will be the one in which the total of the rated values of steam extracted and steam used by auxiliaries is least.

To illustrate the ecomony of steam extraction, let us assume that in a given station fifteen per cent of the total station evaporation is needed for feed water and other heating and that just this amount is supplied by the exhaust from non-condensing auxiliaries. Now suppose that, by substituting other types of auxiliaries, their steam con-

sumption could be reduced to four per cent of the station evaporation. Then most of the steam used in feed water heating could be bled from the main units, and the gain would be roughly the amount of work in the main units done by the extracted steam in expanding from throttle pressure to the bleeder pressure. In the above case the gain would be four per cent or more of the station evaporation.

The extraction of steam from the main units, while usually economical, sometimes raises complex questions and when it is contemplated the matter should be taken up with the manufacturers. One of the difficulties with turbines is in finding points for extraction where the pressure will be low and still under all load conditions will be above atmospheric pressure. It is only practicable, of course, in multi-stage turbines or multi-expansion engines.

In computing steam-rates for heat balance it should be noted that some of the auxiliaries may require nearly maximum power at all times, either through inability or through failure of the operators to adjust them to changes in conditions.

CONDENSER EQUIPMENT

In waterworks practice, condensers and auxiliaries are usually bought with the main unit which they serve. The determination of their size and type is frequently left to the manufacturer of the main unit, especially when he guarantees the overall economy of the outfit. The manufacturer, however, is not usually informed upon all the details of station economies, such as its heat balance, cost of steam, etc. It is better for the purchaser to gather all the necessary data, to analyze the situation in advance, and then to specify definitely what he wants.

CONDENSERS

Condensers of the surface type are ordinarily the only ones well adapted to waterworks service. Those of other types need no discussion here. Condensers for pumping engines or steam-turbine pumping units may be either of the waterworks type (in which all of the water pumped by the unit passes through the condenser and outside of the tubes) or of the standard type. Surface condensers for other service are practically always of the standard type.

In selecting a condenser for a pumping unit the choice between the waterworks and the standard type is first to be settled. The only

advantages of the waterworks type are that it dispenses with a circulating pump and the large volume of cooling water results in a greater mean difference between cooling water and exhaust steam temperatures. Its disadvantages are as follows:

1. It causes a loss of head in all of the water passing through the main pump. This loss of energy may be greater than the power required to drive the circulating pump for the standard type, particularly when the total pumping head of the main unit is low or the capacity large.

2. Due to the low velocity and uneven distribution of cooling water, the heat transfer constant is much less than in the standard type. This fact may offset the advantage of large temperature difference.

3. It is difficult to clean where the tubes are fouled by the water.

4. It is heavier and more expensive than the other type, even when the surface is the same.

5. It chills all of the condensate down practically to the water temperature, thus wasting heat.

6. Usually located in the suction pipe, there is not much chance for choice as to its position and frequently it must be placed in dark, hot or inaccessible places, also necessitating locating the auxiliary pumps in similar places near-by.

The waterworks type of condenser has been generally used, particularly in connection with pumping engines. Its choice is frequently justified, but custom seems to have led to its use in some cases when the standard condenser might have been better.

When a condenser of the waterworks type is to be bought, the purchaser should specify in addition to mechanical details the vacuum at given loads, the maximum heat-transfer coefficient and the maximum loss of head in the condenser. The loss of head should not be more than two feet and preferably should be less than one. It can be kept small by providing liberal space between the outermost tubes and the shell.

When a condenser of the standard type is to be bought, the purchaser should specify, in addition to the above, the maximum rise in cooling water temperature. The assigning of logical values for these quantities requires consideration, among other things, of the power required to drive the circulating pump and the cost of furnishing that power. The required cooling surface, and therefore the first cost of the condenser, will be decreased by increasing the water

velocity through the tubes or by increasing the quantity of cooling water, or by both, but the cost of driving the circulating pump will also be increased as a result.

By suitable design, standard condensers may be made to keep the temperature of the condensate within 3 to 5 degrees of the exhaust temperature and it is well to specify that this be done.

CONDENSER AUXILIARIES FOR STEAM-TURBINE UNITS

Circulating Pumps. Circulating pumps are nearly always of the centrifugal type and may be driven by electric motors, steam or water turbines or may be direct-connected to the centrifugal pump shaft of the main unit.

The direct-connected circulating pumps usually are the most economical of power. Their disadvantage is that a vacuum cannot be established before the main unit is in operation.

The circulating water is usually taken from the suction piping supplying the main unit and, after passing through the condenser, is returned to the same piping. If the piping in the cooling water circuit be tight, and the highest point be no more than 30 feet above the supply level, the total head under which the circulating pump must operate will be limited to the friction losses in the piping and in the condenser, since the water will pass over the high pionts in the circuit by syphonic action.

Water turbines, direct-connected to the circulating pumps, often make a very satisfactory driving motor. The driving water is taken from the discharge piping of the main pump and returned to the main suction piping. If the economy of the main pumps be reasonably good, this method usually will require less boiler steam than any type of steam-driven or electrically-driven circulating pump.

Occasionally electrically-driven circulating pumps may be the logical choice, as in stations where electric power is produced reliably and economically within the station. Where continuous operation is important, they are inferior to pumps driven by the other means, on account of the danger of interruptions in electrical circuits.

Circulating pumps driven by steam turbines, connected thereto either directly or through reduction gears, are generally applicable only to large installations where the main unit develops one thousand horse-power or more. In a smaller installation the power requirement of the circulating pump is so small that the steam consumption of the driving turbine is excessive in proportion.

In the sizes and for the heads ordinarily required the efficiency of centrifugal circulating pumps will be quite good, ranging from 60 to 80 per cent. Since the total head upon them is usually low the suction lift should be small, and preferably less than 10 feet, to secure good efficiency. The efficiency of a water-turbine driving a circulating pump is usually considerably higher than that of the pump. The water rate of non-condensing auxiliary steam turbines suitable for driving circulating pumps will range from 130 pounds per B. H. P. for turbines of 4 brake-horse-power, to 50 pounds for the largest size required in waterworks service.

Vacuum and Condensate Pumps. Wet vacuum pumps, or those removing both air and condensate from the condenser, when used with surface condensers, are practically always driven by steam engines, and may be either of the piston or the rotary, positive displacement type. They are used most widely where vacua of less than 28 inches are required, but some makes are suitable for high vacuum service. They cannot elevate the condensate more than a few feet above their own level, but when high lifts are required those of the rotary type are sometimes provided with an auxiliary rotary condensate pump mounted upon an extension of the shaft. Of the two types, the piston pumps usually will be the lower in first cost and maintenance cost and will require more steam for operation.

Dry vacuum pumps are used most commonly for high vacuum service, but considerations of simplicity and the cost of furnishing driving power may make some types of them appropriate for low vacuum work. Where used as auxiliaries for steam-turbine units with surface condensers they may be of the steam-driven, piston, the steam-driven, rotary, the steam-jet ejector or the hydraulic type. The displacement capacity and driving power required in dry vacuum pumps will vary about in inverse proportion to the absolute pressure in the condenser. The sizes usually needed in waterworks pumping stations are small and the power requirement, measured in brake-horse-power, is also small, although their low efficiency makes their steam consumption important.

Steam-driven, dry-vacuum pumps are best suited for use in connection with large units. A pumping unit using 8000 pounds of steam per hour, operating with 28.5 inches of vacuum and fitted with a steam-driven air pump, will require an air pump power of only 2 horse-power, but the steam consumption of the air pump will be over 100 pounds per horse-power-hour. As the size of the steam-driven

air pumps is increased their steam rate becomes better until a rate of 40 pounds per horse-power-hour may be had with pumps of 15 horse-power or more.

Hydraulic air pumps and steam-jet ejectors may be secured in sizes consistent with main units of about 300 horse-power or larger. With other conditions equal, their power requirement will vary about in direct proportion to the size of the unit served, differing from that of steam-engine-driven pumps in this respect, so that their most favorable comparison with the engine-driven pumps in the matter of power will occur in the smaller sizes.

Hydraulic air pumps, for general service, are equipped with a pumping element to supply the hurling water and, depending upon the manufacture, this element may be in the same casing as the air-displacement element or in a separate casing. For water-works service, hydraulic air-pumps having an independent air-displacement element, as in those of the Worthington type, are usually preferable. No pumping element is usually needed because the hurling water may be taken from the mains more economically than from a hurling-water pump. If the head in the mains is as much as several hundred feet, however, it may be more economical to use a water-turbine-driven hurling-water pump. When the hurling water is taken from the mains it is returned to the system at some convenient point on the suction side of the main pumps. In such cases the air pump must be set above the highest static water level in the main suction system. When the hurling water is supplied by the auxiliary pumping element, the water is circulated through a tank on a closed circuit and the entire apparatus may be placed at any convenient elevation. Worthington hydraulic air pumps require hurling water under a head of not less than 80 feet. When the pressure head in the mains is considerably more than 80 feet the hurling water is sometimes passed through a water-turbine driving the condensate pump, thus utilizing all or part of the excess head. When hydraulic air pumps can be supplied with water from the main pumps they are apt to be more economical of power than either the steam-driven pumps or the steam-jet ejectors, just reversing the usually-accepted relationship.

Steam-jet ejectors usually must be of the two-stage type to produce satisfactory vacua. Those having surface inter-condensers, or inter-coolers, between the stages are generally preferable. For similar conditions the steam consumption of the two-stage ejectors without inter-coolers is about double that of ejectors with inter-

coolers. When the steam from the steam-jet ejectors is utilized in feed-water heating or other heating it is often led to an open heater where the entrained air may be liberated. Sometimes there is provided an after cooler in which the effluent steam is condensed as in a closed heater. Unless the cooling water used in ejectors be feed-water, the heat abstracted obviously will be wasted. When the main units are of 600 horse-power or less capacity, the two-stage steam-jet ejector with inter-coolers will require no more steam than a steam-driven, piston-type pump. With larger units the comparison will favor the latter type of air pump. One of the objections to both steam-jet ejectors and hydraulic vacuum pumps is the lack of opportunity for capacity variations. In large installations this difficulty is sometimes partially met by providing two air pumps, one of which may be shut down in seasons when the vacuum is low.

Condensate pumps elevating the condensate to the heater may be of the centrifugal type and usually driven by water-turbines or electric motors, or they may be direct-acting, steam pumps. In some cases centrifugal condensate pumps may be driven from the shaft of an adjoining auxiliary serving the same main unit. The net work done in most cases is very small and the efficiency of either type is low. When the water heads are suitable and the main pumping units fairly economical the water-turbine-driven centrifugal pumps will require only one-half to one-quarter as much power as the steam pumps. Electrically-driven, centrifugal condensate pumps may be advantageous when current is produced cheaply within the station and where occasional interruptions in service would not be especially serious.

CONDENSER AUXILIARIES FOR PUMPING ENGINES

Pumping engines are well adapted to driving attached, reciprocating air-pumps and condensate-pumps but cannot be fitted economically with attached circulating pumps. Turbo-centrifugal pumping units may be directly connected to their circulating pumps but not to their air and condensate pumps. The most economical vacuum is of course somewhat lower with pumping engines than with turbines. Except as it may be influenced by these facts, the problem of choosing condensing equipment for the two classes of units is generally the same. Auxiliaries of any of the types discussed in the preceding paragraphs may be used more or less fitly, in connection with pumping engines. Attached air pumps and condensate pumps are reliable, easy to

maintain and highly economical of power, but under equal conditions they are higher in first cost than any other type of separatively-driven pumps. The attached air pump must have relatively a large displacement capacity to give satisfactory service in starting and at low speeds.

COMPARATIVE POWER REQUIREMENTS OF CONDENSER AUXILIARIES

In order to show approximately the comparative power requirements of various types of condenser auxiliaries, the tabulation below was compiled mostly from data offered by bidders at Memphis, Tenn., in connection with a 650 brake-horse-power, 15 million gallon, steam-turbine-centrifugal pumping unit, operating under 200 feet total head. The main unit requires about 15 pounds of steam per water-horse-power-hour and operates at 28.5 inches of vacuum. The power requirements are expressed in pounds of live steam chargeable directly or indirectly to the auxiliaries. The condensate is lifted through a total head of 80 feet, including suction.

	BRAKE HORSE POWER	POUNDS OF STEAM PER HOUR
Circulating pump:		
Driven by main pump shaft	7.0	84
Driven by non-condensing steam turbine	7.0	550
Driven by water-turbine	7.0	120
Driven by electric motor, using current from house generator (generated at 24 pounds per KWH.)	7.0	175
Dry air pump:		
Steam-driven, flywheel, piston pump, non-condensing.	2.0	220
Hydraulic, using water from mains	5.0	75
Same with separate hurling-water pump, driven by non-condensing steam turbine	7.5	600
Steam-jet ejector, 2-stage with inter-condensers		200
Condensate pump:		
Direct-acting steam pump	0.6	150
Electrically-driven centrifugal, using current from house generator	2.0	60
Water-turbine-driven centrifugal, using water from mains	4.0	60

The figures on water-driven condensate pumps and air pumps are based upon the driving water being passed through these auxiliaries in series. The data in the tabulation are directly applicable only to this particular installation.

A cross-compound pumping engine designed for the same head and capacity as the above unit, operating with 28 inches of vacuum, would require about 60 pounds of steam per hour to drive attached air pump and condensate pump.

BOILER FEED PUMPS

Except in the largest pumping stations there is not much opportunity for choice of type of boiler feed pumps. Unless the average station evaporation is more than 1000 pounds per minute it is doubtful whether centrifugal feed pumps will be found advisable. The objectionable features in centrifugal feed pumps of small capacity are their low efficiency and narrowness of water passages. A combination of high head and small capacity results in narrow impellers and poor efficiency. A pump with a capacity of less than 100 gallons per minute would have an opening at the tips of the impellers not much wider than a crack. With impellers of this shape any tendency of the water to erode the impellers or deposit scale upon them and any undue wear of the rings have a serious effect upon the performance of the pump. In capacities of 150 gallons per minute the efficiency and operating capacities of centrifugal pumps are reasonably satisfactory and both improve with further increase in capacity. As compared with direct-acting pumps their advantages in the way of simplicity, ease of maintenance and producing a steady water-flow are manifest.

The choice of driving mechanism for centrifugal feed pumps seems to be limited to steam turbines and electric motors. Investigations for the new Kansas City pumping station indicated that water turbines would be unsatisfactory, as the combination of considerable power requirement and low pump efficiency resulted in too large a driving-water demand. In this case it is planned to use electrically-driven centrifugal feed pumps ordinarily and to aid reliability by providing a reserve steam pump.

For stations of small or medium capacity nothing appears to be better than direct-acting steam pumps of the plunger type.

STOKER DRIVES

Vertical, high-speed, steam engines are probably the most common type of stoker-driving mechanism for pumping stations, except for stokers of the steam ram type. Steam engines are unequaled in adaptability to graduated, wide range, automatic, speed regulation, which is a highly desirable quality in stoker mechanism.

Electric motors are used considerably. They possess the advantage of simplicity. If their current supply is generated economically they may be more economical of power than steam stoker engines. They are poorly adapted to automatic speed regulation. They are somewhat deficient in reliability, due to the possibility of trouble in the electrical circuits, but where underfeed stokers are used the amount of fuel on the grates will keep up steam pressure long enough to remedy minor troubles of such nature.

Water turbines have been little used for driving stokers but seem to offer fair possibilities in some cases. They equal electric motors in simplicity and considering the source of power supply would usually excel them in power economy and reliability. They are easily adapted to automatic speed control through a throttling valve, but cannot operate through as wide a speed-range as either steam engines or electric motors.

Steam turbines do not seem well adapted for stoker drives in waterworks stations, although used considerably in large power plants. In the smaller sizes it is doubtful if their upkeep cost is less than that of an engine, and their power economy is very poor. Where the boiler units are larger than 250 horse-power, individual driving mechanisms for each stoker are desirable, as they permit independent speed adjustment and increase the reliability of the station. Frequently a common-line-shaft for the entire boiler room is used and driven by one engine or motor with a duplicate engine or motor in reserve. This arrangement is simple but has not much else to recommend it.

Individual steam-driven stoker engines are being used in the new Memphis pumping station where the boiler units are of 350 horsepower nominal capacity. Ordinarily each engine will drive its stoker by direct connection to the speed shaft. Short jack-shafts connecting the stokers in pairs are provided in such manner that if desired one stoker engine may be used to drive its own stoker directly and also drive the neighboring stoker through the jack-shaft, in which case the neighboring engine will be disconnected from the stoker and jack-shaft. This arrangement is for emergency use and ordinarily the jack-shaft will be idle.

When stokers are driven in groups, a variable speed transmission device such as the Reeves is sometimes inserted between the line shaft and each stoker. This arrangement is preferable to a common-drive system, but is not readily adaptable to automatic control.

MECHANICAL DRAFT DRIVING MECHANISM

Modern mechanical draft fans are usually of the high-speed multi-vane type and must be driven by steam turbines or electric motors. If driven by vertical engines the maximum rotative speeds of fans are usually about 400 R.P.M. and they must be of the steel plate type. Steel plate fans require considerable space and their characteristics are usually less satisfactory than those of multi-vane fans. Their principal advantage lies in their adaptability to steam engine speeds.

For driving high speed fans the choice between steam turbines and motors depends upon the individual station conditions. Motors are desirable on account of their simplicity and in some cases on account of economy, but are not so well adapted as turbines to automatic speed regulation and are slightly deficient in reliability. With underfeed stokers continuous operations of the fans is essential; with chain grate stokers the fans may be essential only for high ratings.

Fans should have driving mechanisms entirely independent of those for the stokers. The air supply to each boiler should be controlled individually and preferably by automatic means, either by varying the speed of individual fans, by varying the positions of individual dampers in the air supply ducts or by both methods. The use of dampers to control air supply results in waste of fan-drive power and this is about the only objection to such use of them. Where electric power is produced reliably and economically within the station, electrically-driven fans with dampers for air control may be preferable to either turbine-driven or electrically-driven fans with automatic speed regulation. Automatic speed controllers for electric motors are expensive and complex. Manual speed controllers are simple and inexpensive and often may be used to advantage where motors are used to drive the fans. The shaft power required by fans varies about as the cube of the speed; hence reducing the speed will substantially reduce the electrical input, no matter whether the motors be of the alternating or the direct current type. By using the manual speed controllers the fans speed may be approximately adapted to the boiler load and an automatically operated damper in the air duct may be used for closer regulation of the air supply.

When fans are driven by steam turbines, they may be connected directly or through reduction gears. The reduction gear units are

more economical of steam and decision as to whether they should be used depends upon their size and cost and upon the value of the steam saved.

Frequently several boilers are served by a common main air duct and supplied by a single large fan, with a duplicate fan in reserve. Choice between this arrangement and one individual fan depends upon the number and size of boilers, load variations and other conditions in the station. Individual fans permit of short and direct air ducts and of regulating the fan speeds independently to suit the requirements of each boiler. They also permit of the fans being designed for a reasonably narrow capacity range, since the range corresponds to the load variations of only one boiler.

A common fan system has the advantage of simplicity but requires control of the air supply at the individual air duct damper and requires the fans to be operated through a wide capacity range, corresponding to the range from minimum to maximum boiler room load. Extreme load variations in the ratio of four to one are not uncommon in pumping station boiler rooms and the corresponding ratio of fan power requirement might be as high as 15 to 1. Under these circumstances a common fan system would be wasteful of power, since a fan cannot be designed for economical operation through such a wide range of conditions.

WATER WORKS PUMPING STATIONS[1]

By Charles B. Burdick[2]

It is the purpose of this paper to outline the general principles of pumping station design and to cite a few examples of recent construction, referring more particularly to the buildings for housing water works equipment.

The average water works involves an investment of not less than $35.00 per capita or $3,500,000 in a city of 100,000 people. Of this large investment often not more than ten per cent represents structures visible to the eye of the ordinary citizen. To the casual observer water works buildings present the only evidence of the excellence of the plant, except the water delivered, and his impression as to the property is likely to be based upon what he can see.

Fundamentally there is no reason why the water works station should not present the same attractive appearance as the city hall or any other municipal building. It should be permanent, clean, and as easily kept clean as a modern hospital, for it handles a commodity used in every home. An ornate design justified in a city hall or a courthouse would be out of place in a pumping station. Rather it should represent the masculine in architecture without undue pretension, strong and permanent in its lines and materials, frankly adapted to its purpose, and presenting an appearance agreeable to the eye. This will require compliance with laws of good architecture, which have been thus concisely expressed by Horatio Greenough:

> A scientific arrangement of spaces and forms to functions and site; an emphasis of features proportioned to their gradated importance in function; color and ornament to be decided and arranged and varied by strictly organic laws having a distinct reason for each decision; the entire and immediate banishment of all make-shift and make-believe.

PERMANENCE

Water works construction is now sufficiently standardized so that it is possible to lay out pumping plants subject to enlargement in

[1] Presented before the Detroit Convention, May 22, 1923.

[2] Alvord, Burdick and Howson, Engineers, Chicago.

such manner that the buildings may be useful indefinitely. The pumping and power equipment should be arranged with the idea of expansion. It is usually practicable to build only for a moderate time in the future, but it costs little to lay down the indefinite future additions on paper, and so to locate the building, and so to arrange the equipment that extensions may be made without destroying the usefullness of important parts of the plant. It is all too common to find layouts that have expanded piecemeal according to the path of least expense, which must be torn out and rebuilt, because further expansion is impracticable. We can see farther into the future today than was possible a generation ago. There may be radical improvements in water works equipment hereafter, but, if the general plan of expansion has sufficient elasticity, the probable future can be accommodated.

In the ordinary water works plant, steam operated, there is, first, the heart of the plant, so-to speak, consisting of the main entrance, offices, and possibly a laboratory which may be grouped, and will need little further expansion. The engine room and the boiler room, after providing for the present and the immediate future, may be expanded along parallel lines without necessarily spoiling the architectural symmetry. It is wise to be liberal in selecting dimensions. This tends toward permanency.

If the water is filtered, it is desirable in small pumping stations to centralize the "business end" of all the station operations on account of facility in supervision. This complicates the design, especially the provision for future expansion, and centralization is not always possible when filtration is added to an old water works. In the layout of a new plant, however, it is practicable so to coördinate the expansion of pump room, boiler room, filter plant, coagulation basin, and clear well, that each may be enlarged in an orderly manner with convenience of access between the operating parts and the administrative center of the group. Basins and reservoirs may expand, if necessary, forward from the building, utilizing a space covered over by lawn. Plants in cities up to 100,000 population, or somewhat more, may thus be designed without the necessity for separating the pumping and filtration plants. A compact arrangement is quite necessary for economical operation in a small city where it may be desirable to operate filters without adding to the number of employees.

FIREPROOF CONSTRUCTION

The modern water works station is fireproof throughout for obvious reasons. Permanency requires it. It should be the last building to burn in any community. Many water works stations are practically fireproof except for the roof construction, windows, and the doors. It is practicable to build stations today without using a stick of wood, and at moderate costs as compared to wood. Mill-work has increased in price to such extent that there is little difference between wood and metal frames, and concrete and tile construction is generally used for roofs in the most modern stations.

BUILDING MATERIALS

For underground structures or for other structures, more or less concealed and protected from the weather, concrete gives excellent service. Where exposed to view or subjected to the action of the elements, it is not proving a satisfactory building material. Whereever possible it is wise to design reservoirs so that they may be filled over and sodded, thus protecting the concrete from the expansion and contraction of hot sun and winter cold, and incidentally better protecting the water from extremes of temperature

For superstructures, brick and stone are the most satisfactory materials for exteriors, terra cotta may be useful upon the interior or exterior. Upon the interior the surface should be clean and non-absorbent. Concrete floors are only satisfactory in the cheaper structures where it may be successfully used if covered with a heavy non-absorbent paint especially adapted to concrete. In the better stations terrazzo or tile is justified.

Walls, particularly where damp, as in the pumping pits, should be faced with a non-absorbent substance such as enamel brick built at least head high. Above this plane pressed brick is satisfactory. At present a rock plaster is available almost as hard as stone which can be worked into very attractive panel designs at moderate cost.

For the roof, exposed steel trusses are generally used with steel purlines and a roof covering of reinforced concrete or tile. In order to prevent sweating in cold weather a double ceiling is desirable. This may be accomplished by rock plaster on metal lath hung from the purlines. Thin concrete roofs usually become a nuisance at certain times from dripping. A single thickness of 5 inches is usually sufficient to prevent the serious collection of drops. A double ceiling

completely eliminates the trouble and costs comparatively little more. Skylights and ventilators must be guarded with gutters for satisfactory results.

It is proposed to cite a few examples of recent pumping station construction with illustrations and figures of cost. Practically all of this work has been done in co-operation with Mr. Victor A. Matteson, Architect, Chicago.

DES MOINES PUMPING STATION

The new 21st Street pumping station at Des Moines, Iowa is illustrated in figures 1 to 5. This is a steam station. It pumps the entire water supply of the city in one operation from the ground water collecting galleries into the pipe system against direct pressure. The rates of pumpage at the present time are as follows:

Minimum night rate, m.g.d.	6.5
Average day, m.g.d.	10.0
Momentary peak, m.g.d.	18.0
Maximum fire demand, m.g.d.	24.0

The pumping plant consists of three DeLaval turbo-centrifugal geared units, two of 15, and one 25 million gallons capacity. These pumps operate at a 269 feet total head with 200 pounds boiler pressure and 100° of superheat. The two smaller of these pumps developed duties on test ranging from 150 to 114 million foot pounds per thousand pounds of steam at full capacity and half capacity respectively. The larger pump is guaranteed to deliver 161 mil. duty at full, 164 at three-fourths and 144 at one-half capacity.

BOILER PLANT

The boiler plant consists of four 323 H.P. Springfield water tube boilers. One boiler is served by a LaClede-Christy natural draft chain grate stoker. Three boilers are equipped with Harrington chain grate stokers operating on natural draft up to 125 per cent rating, and forced draft up to 200 per cent rating. The plant burns a low grade of bituminous screenings (Poke County, Iowa), ranging from 8,000 to 10,000 B.T.U. The individual boilers and stokers in this plant developed on test from 72 to 74 per cent efficiency when operating on natural draft slightly above boiler rating, and 70 per cent on forced draft at slightly under 200 per cent rating.

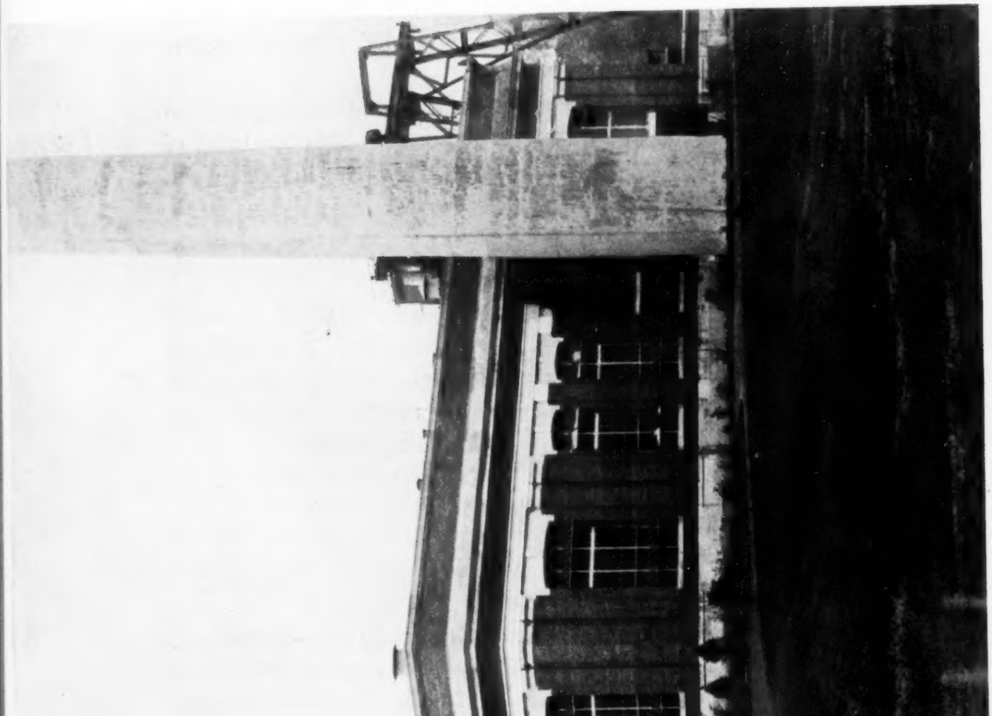

FIG. 1. WATER WORKS PUMPING STATION, DES MOINES, IOWA
Note gantry crane for coal handling in rear of building

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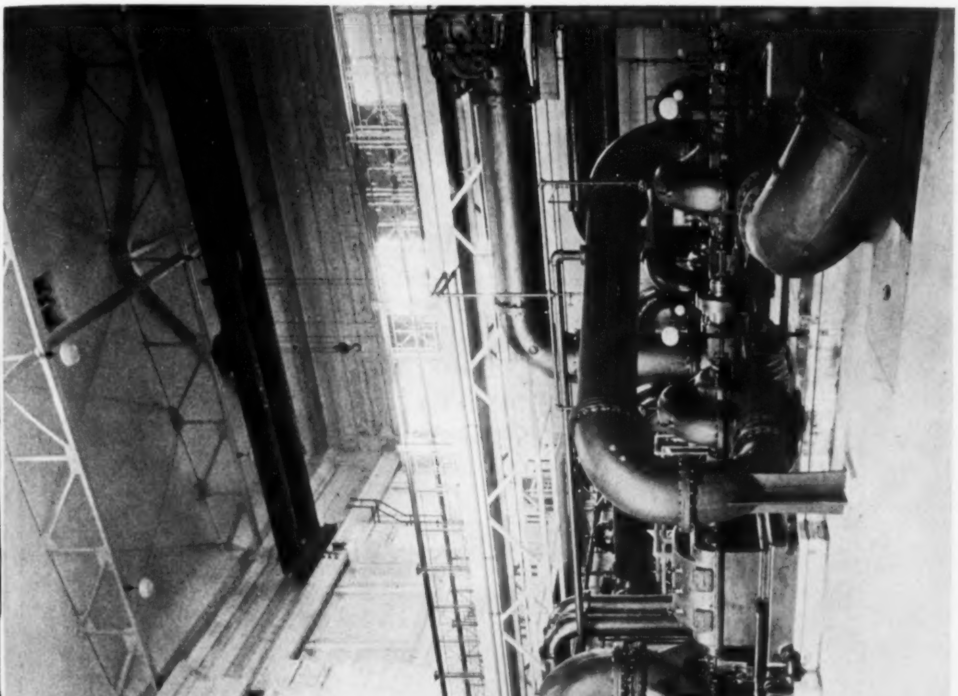

FIG. 2. PUMP ROOM, DES MOINES PUMPING STATION, HOUSING TURBO CENTRIFUGAL PUMPING EQUIPMENT

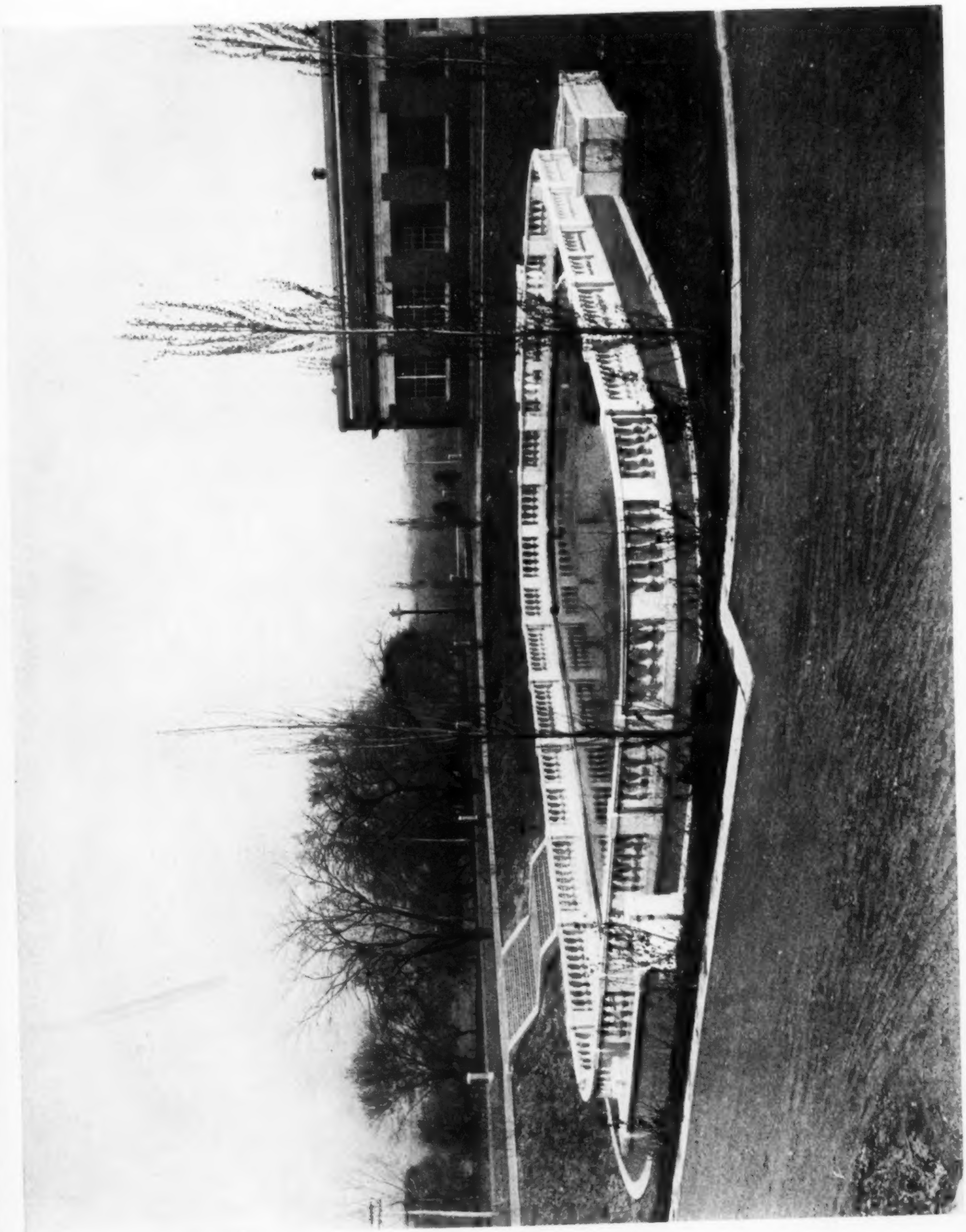

FIG. 3. IMPROVEMENT OF GROUNDS, DES MOINES PUMPING STATION

Roads and buildings were elevated above high water. This view illustrates the improvement of a borrow pit

This boiler and pumping plant serves the city on about half the tonnage of fuel per unit of water pumped required by the old pumping station, served by hand-fired tubular boilers and compound crank and flywheel pumps. The greater part of the saving is secured by the improved boiler plant.

COAL HANDLING

The matter of handling coal is a difficult one in a water works boiler plant by reason of the magnitude of the peak load as compared to the comparatively small average load. Coal handling equipment of the type adapted to electric lighting practice often fails to show economy when applied to the small tonnage burned by water works, on account of fixed charges. The device adopted at Des Moines

Fig. 4. Shops and Garage Building, Des Moines Water Works

consists of a gantry crane feeding from cars or coal pocket to an overhead bin in the boiler room. It also picks up ashes, dumped to the ash pocket by hand, loading the same into cars or trucks. By the use of this crane one man unloads all cars not dumped, and handles all coal and all ashes for a 24 hour shift in three hours or less. The coal handling scheme at Des Moines at the present price of labor a little more than "breaks even" with hand coal handling, labor and fixed charges considered. Its installation was considered warranted in view of the probable future increased cost of labor.

BUILDING GROUP

The group of buildings comprising the new water works pumping station at Des Moines consists of the main pumping station and boiler room, a shop and garage building for the accommodation of all

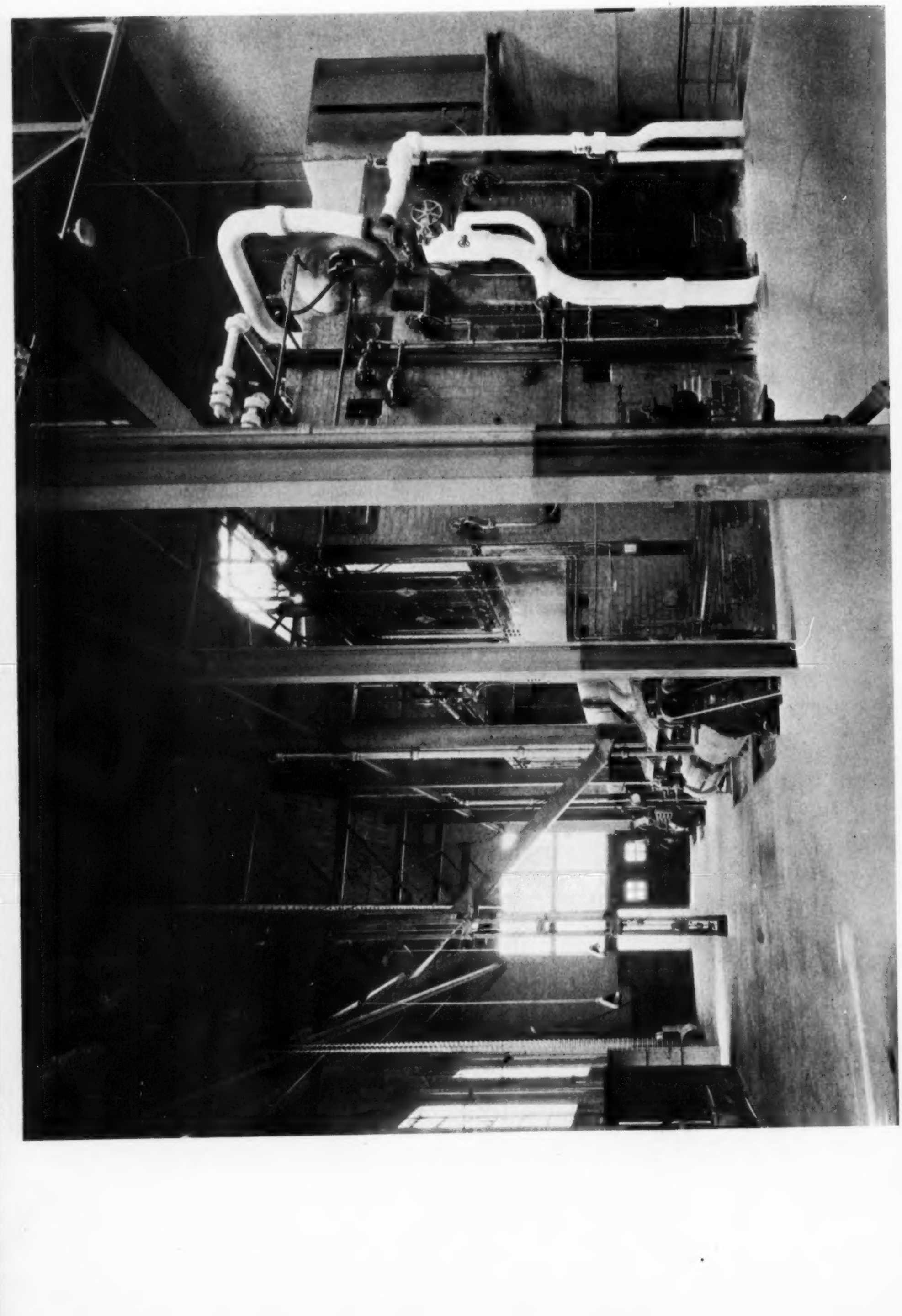

Fig. 5. Boiler Room, Des Moines Pumping Station

automobiles and trucks used by the Water Department, a warehouse, with pipe yard adjoining, for storing pipe, fittings and miscellaneous supplies; also a group of cottages housing four families of water works employees.

The main pumping station consists of a pump room containing space for eighty million gallons in pumping capacity. Fifty-five million gallons capacity is at present installed. The boiler room contains 1300 H.P. in boilers and space is provided for enlargement that may be required after 1940.

Adjoining the main entrance to the pumping station are located an office for the chief engineer, a laboratory, and toilet accommodations for the public. Employees' toilet rooms are located between the pump and boiler rooms. Galleries are provided in the pump room for the accommodation of visitors, so that the pump room may be seen without interfering with the operation of machinery.

All foundations are constructed of heavy reinforced concrete. The pumps are set 13 feet below the high water line, thus necessitating a heavy pump pit floor and walls to resist upward and inward pressure. The pumps are located in this way in order to draw from the gallery system in extreme low water.

The pump room is finished with terrazzo floors and white enamel brick walls up to the top of the wainscot at grade line. Above this point the walls are paneled and coated with rock plaster. The roof is supported by steel trusses carrying Federal cement tile with a composition roof covering. Steel windows, doors and trim are used throughout.

The boiler room is finished with concrete floors, with walls of common brick painted. The entry way and halls are floored with terrazzo, and provided with terra cotta walls. The exterior of the building is of dark red tapestry brick with Bedford stone trim.

The shops and garage building exterior finish is similar to pump house. The interior is finished with concrete floors and common brick walls, and the whole is surmounted by a timber mill construction roof, slow burning type, and covered with composition roofing. Steel window sashes are used. The remaining millwork is of wood. This building provides all facilities for the maintenance of the water works motive power and contains a wood shop, machine shop, paint shop and in the rear a stable for the accommodation of one team.

The warehouse building resembles a small freight house in general plan with an office space in the front where all water works labor is

handled and assigned to its daily tasks. A siding runs parallel with the warehouse with platforms on both sides, so that freight unloaded may be wheeled through the storeroom and loaded on wagons or trucks. Heavy freight such as pipe and large fittings may be unloaded from the opposite side of the cars and stored in the pipe yard. This building is surmounted by a mill construction wood roof. Floors are of concrete and the office walls are plastered. Wood millwork is used throughout this building.

Three wood and stucco English cottages provide for four families. One cottage contains five rooms, one six rooms, and one double cottage contains two six-room apartments. Each apartment is provided with concrete cellar, furnace heat, plumbing, maple floors, plastered exteriors and shingle roofs. These apartments are rented to employees at cost. The rent charged is $30.00 per month per apartment exclusive of heating and light.

ORLANDO WATER WORKS AND LIGHT PLANT

At Orlando, Fla. the new station is now nearing completion. This accommodates the water filtration plant of four million gallons capacity, electrically driven centrifugal pumps of 12 million capacity augmented by four million of steam pumping capacity in another station. The generator room contains 4,000 K.W. in turbo-generators with space for 2,500 additional K.W. The boiler room contains 1500 H.P. in boilers, oil fired.

The Spanish type of architecture was used, as especially adapted to a warm climate. The boiler room is open on the rear, the boiler fronts being protected by open archways. The walls are of brick with exterior cement plaster. Roofs are supported on steel trusses with concrete slabs and composition surface. Red tile is used for sloping roofs and wall caps. The interior of the pump room is plastered. All other wall surfaces are of common brick painted. Floors are of red quarry tile.

Table 1 hereinafter shows the cost of the Orlando building including filter house and concrete filter beds; also clear water reservoir underneath the filters, but does not include cost of filter equipment or any other equipment of the plant except as stated in the tabulation.

MANISTIQUE TOWER

The opportunity was afforded at Manistique, Mich., to combine a small electric driven pumping station and a water tower. The

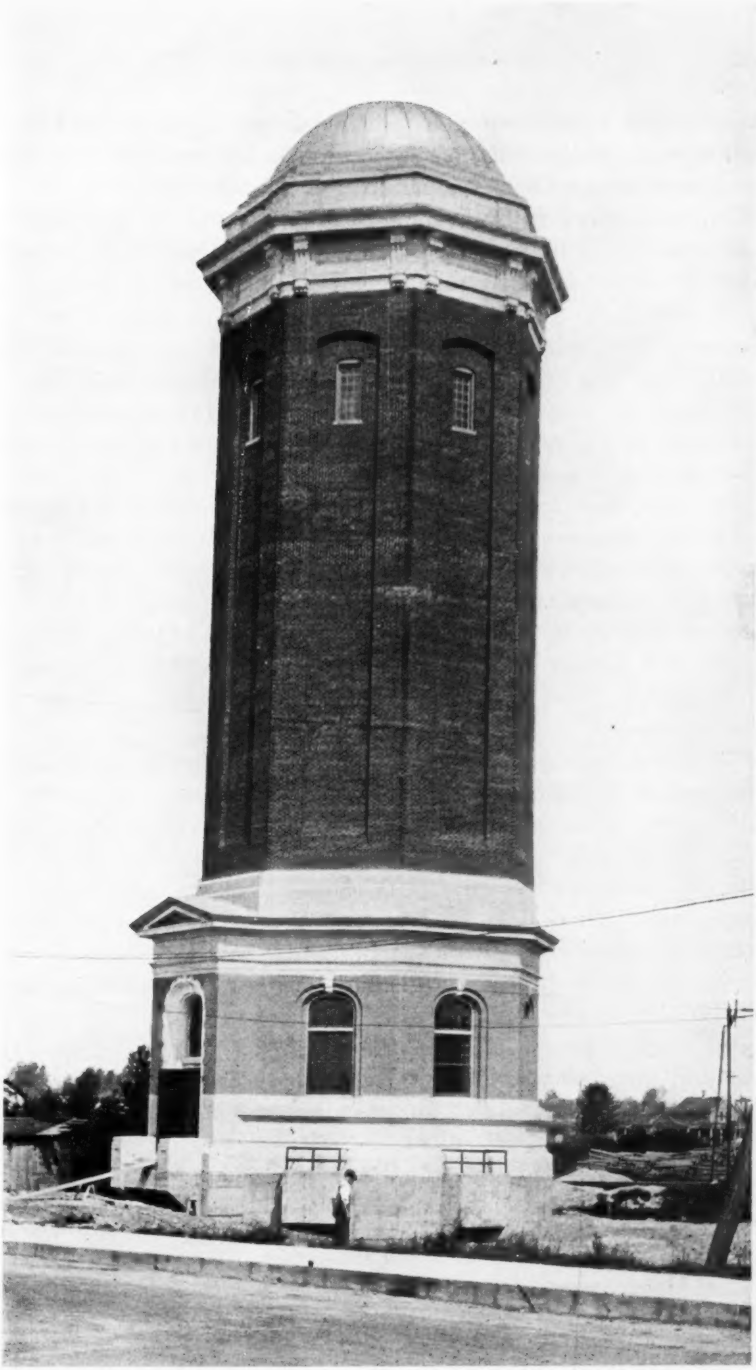

FIG. 6. COMBINED WATER TOWER AND PUMPING STATION, MANISTIQUE, MICHIGAN

Base of tower houses electric driven centrifugal pumps

water supply at Manistique is delivered by gravity, substantially at ground height, to the center of the town where it is pumped electrically into a steel elevated tank surmounting the pump house.

The land occupied by the pumping station was donated by the public spirited citizen upon condition that an attractive station and tower should be built. Manistique is a small city with a population about 7000. A plan was worked out which accommodated the necessary electrically driven pumps in the base of the tower, and the saving thus effected permitted enclosing the tower in an attractive envelop. The cost of the structure thus built is approximately equivalent to an uncovered steel elevated tank plus a separate building of fireproof construction.

The steel tank contains 200,000 gallons. The top is located 107 feet above the ground. It has a hemispherical bottom and is supported on the brick work 64 feet above ground by means of eight short legs horizontally braced. The tower is constructed of brick with red tapestry face brick. The trimming on the lower portion of the tower is Bedford stone and the cornice is constructed of reinforced concrete cast in place. The dome is of zinc supported on wood trusses.

The tower is octagonal outside and 16 sided inside. The brick cross-section is sufficient to support the superimposed load with a unit pressure not exceeding 175 pounds per square inch.

The sixteen sided pump room is 33 feet in inscribed diameter. It is floored with terrazzo with white enamel brick wainscot, and rock plaster walls and ceiling. A false roof is provided over the pump room with drains to catch any drip or leakage from the elevated tank. A cellar under the pump room accommodates all pipes, heating, and plumbing equipment.

The electric pumps are pressure controlled from the tank and start and stop automatically. No attendant is required in the operation of the plant except for periodical visits for inspection and oiling.

The cost of this structure complete is shown in table 1.

GARY STATION AND WATER TOWER

The Gary pumping station and water tower, although built a number of years ago is shown here as an example of what is possible in the use of concrete.

The water tower is simply a housing for a steel elevated tank supported on vertical steel legs entirely independent from the envelop. This plan was followed on account of the necessity for haste in providing a water supply for the city during the building period. The concrete envelop was added later. The shaft of the tower is of

TABLE 1

Cost of pumping station buildings

	COST	CONTRACT DATE	CUBIC FEET (THOUSANDS)†	COST PER CUBIC FEET	COST PRICE BASE*	PRESENT PRICE BASE (MARCH 1923)*	PRESENT COST PER CUBIC FEET‡
				cents			*cents*
Pumping stations:							
Des Moines, Iowa	$220,479	1920–23	810.0	27.0	178	198	30.0
Ashland, Ky	34,194	Oct. 1921	130.0	26.4	159	198	32.8
Orlando, Fla	91,800	Sept. 1922	510.0	18.0	180	198	19.8
Ironwood, Mich.							
Main station	29,155	July 1920	65.0	44.8	269	198	33.0
Sub-stations	9,644	July 1920	7.5	64.2	269	198	47.6
Manistique, Mich	71,379	Sept. 1921	140.0	51.0	156	198	65.0
LaCrosse, Wis	50,834	Nov. 1912	484.0	10.5	100	198	20.8
Prairie du Chien, Wis	21,017	Sept. 1921	77.8	27.0	156	198	34.3
Auxiliary buildings:							
Des Moines garage	51,027	May 1922	390.0	13.1	160	198	16.2
Des Moines warehouse	18,754	May 1922	111.0	16.8	160	198	21.0
Des Moines cottages, 3 cottages, 4 families, 22 rooms	20,430	May 1922	18.0	29.2	160	198	36.0
Ironwood cottages, 2 cottages, 2 families, 12 rooms	16,900	July 1920	16.0	44.5	269	198	33.0

* Building materials United States Department of Labor.

† Each building where more than one. Contents based on outside measurements footing to average roof.

‡ As of date April 1, 1923.

reinforced concrete with a concrete dome roof. The base of all cornices and the facing on the lower one-fifth of the tower is of precast concrete applied in the usual manner where stone is used. The shaft proper is of reinforced concrete with a reinforced concrete dome roof.

FIG. 7. WATER TOWER AT GARY, INDIANA

The pumping station has concrete foundations. The pump room is depressed below the ground level and is lined with white enamel brick. Above grade walls are of brick with buff pressed brick interior face, and precast concrete enterior face. The exterior face blocks are of two colors, gray and dull red.

ASHLAND

The Ashland, Ky., plant exemplifies construction for a small city. It includes an electric driven pumping station with gasoline reserve pump; also a water filtration plant. Construction throughout is entirely fireproof and of good appearance, but no extra money was spent for the sake of appearance.

The entrance to the plant as indicated in figure 8 is through the operating floor of the filtration plant. The filter beds produce the terrace effect indicated in the picture.

Upon the Ohio River the intake problem is important on account of the extreme variation between high water and low water. The low lift pumps are located in a pit 26 feet in diameter and 43 feet deep. They consist of two motor driven centrifugals and one high speed gas engine centrifugal cash $2\frac{1}{2}$ m. g. d. against 65 feet head. Three pumps of the same kind and capacity operate against 275 feet head when pumping to the city. These pumps and the filters are installed on the roof of the clear well.

The filtration plant consists of four beds, total capacity, $2\frac{2}{3}$ m. g. d. High velocity of wash is used from a 35,000 gallon steel wash tank set on the roof of the pump pit.

IRONWOOD, MICHIGAN

This plant develops a ground water supply from driven wells and pumps it against a head of 650 feet through a four mile pipe line of 16 inch diameter. The water is developed from three shallow well groups, each sub-station containing a 2 m.g.d pump. The main pumping station contains two three million gallon electric driven centrifugals and one and one-half million gallon high speed gas engine driven centrifugal. One gasoline driven centrifugal is also installed for reserve low lift pumping.

The buildings connected with the Ironwood Water Works are all constructed from boulders picked up on the water works lot. The saving thus effected as compared to brick was nominal, but it is believed that these building present better appearance than would brick structures in the locality where built.

The main pump house has walls of boulder stone plastered inside on metal lath and painted, floors of concrete painted, and the roof is slate on wood with matched and beaded ceiling oiled, and exposing steel trusses. Three similar sub-pumping stations were built and as

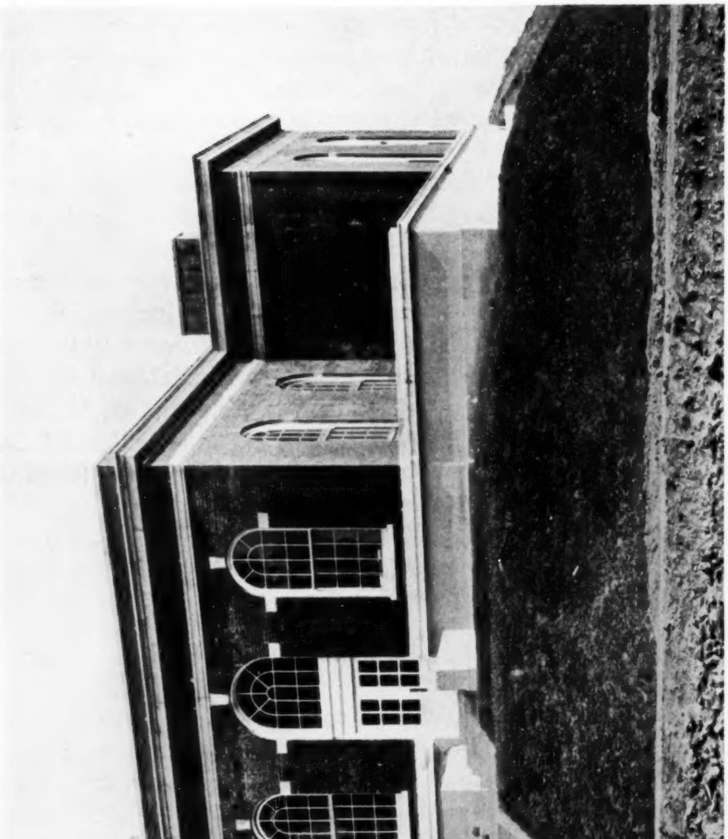

FIG. 8. ASHLAND, KENTUCKY PUMPING STATION AND FILTRATION PLANT

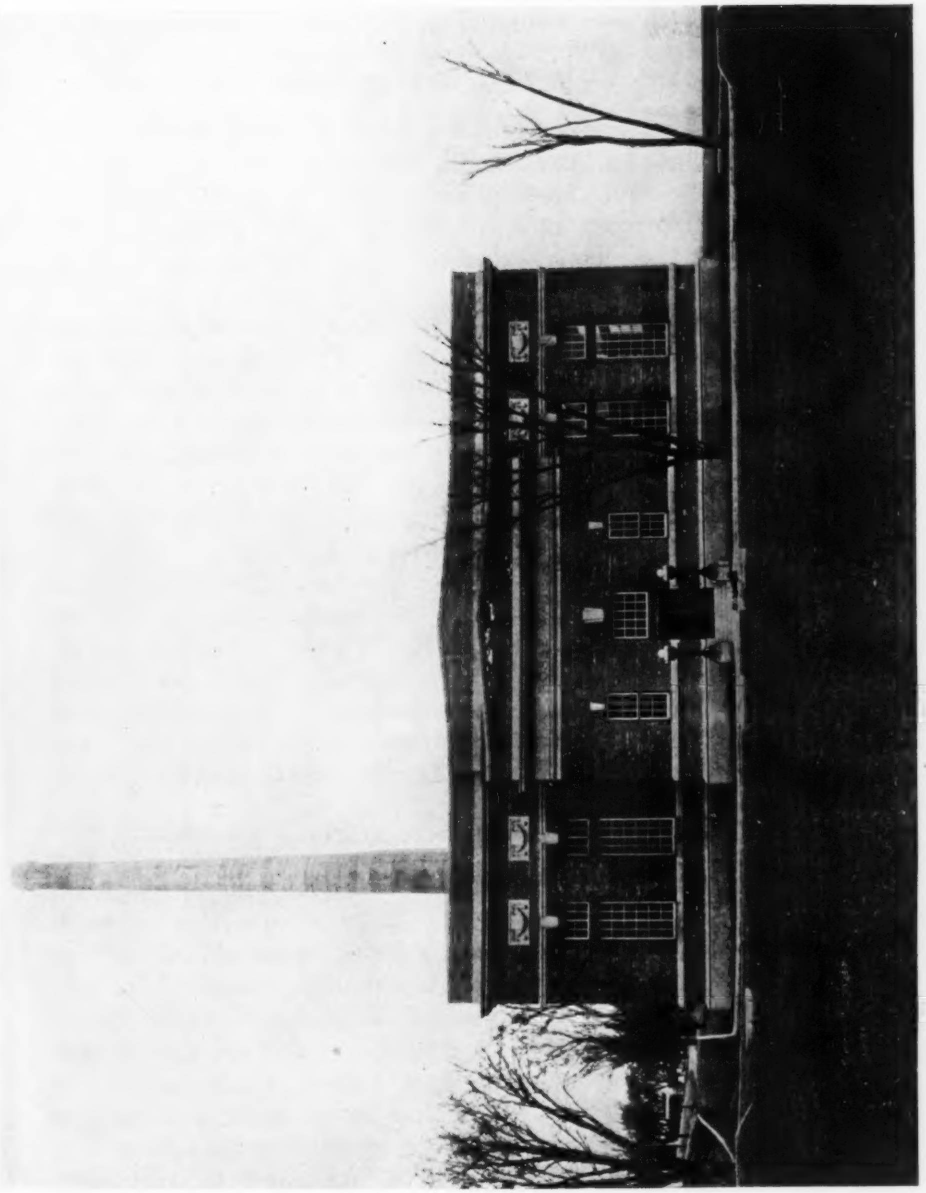

FIG. 9. WATER WORKS PUMPING STATION, LACROSSE, WISCONSIN

the plant is located some distance from habitation, it was necessary to construct two six-room dwellings also built of boulder stone.

PRAIRIE DU CHIEN, WISCONSIN

This plant represents the practicabilities in a small town where the funds available for water works construction were quite limited. This pumping plant consists of a concrete pit 45 feet inside diameter by 24 feet deep surmounted by a mill construction wooden roof with a small brick building attached to the pit at the ground level for office and shop purposes.

This plant is electrically operated. Water is sucked directly from four driven wells immediately outside the pit wall and discharged into the pipe system which is connected to an elevated reservoir on the adjoining bluffs. The pumping installation consists of one motor driven centrifugal 500 G.M., 340 feet head, one 600 G. M. high speed gasoline engine centrifugal, and one 600 G.M. motor driven triplex pump moved from an old pumping station. Space is provided for a fourth pump at some time in the future.

All foundations are of reinforced concrete. The superstructure and the parapet around pumping pit is common brick with moderate priced face brick. All sills, lintels, and caps are built of precast concrete. All roofs are of wood construction. The composition roof covering of the pit is concealed by the brick. The roof of the office and shop structure is finished with cement interlocking tile. Concrete floors are used throughout. Interior walls of brick are painted.

COST OF PUMPING STATIONS

The cost of the pumping stations that have been described and several others are shown in table 1. As the prices of labor and material have fluctuated quite materially during the period in which these stations were built there is shown in the table the date of the contract, the price basis at the time and the price basis at the present time. The table also shows the cubic foot cost of the stations as of the time when let and as of the present time. In computing cubic foot cost the contents of the building have been figured based on outside measurements and taking the height from the footing level to the average outside surface of the roof for each part of the building.

The tabulated price base is the average cost of building materials as published by the United States Department of Labor. This re-

fers to the average prices of 1913 as 100. The use of this price base presupposes a fluctuation in labor equal to the fluctuation in material price. The price of labor generally fluctuates less than the price of material. However, it is true that the efficiency of labor enters into contract cost and it is generally true that, when materials

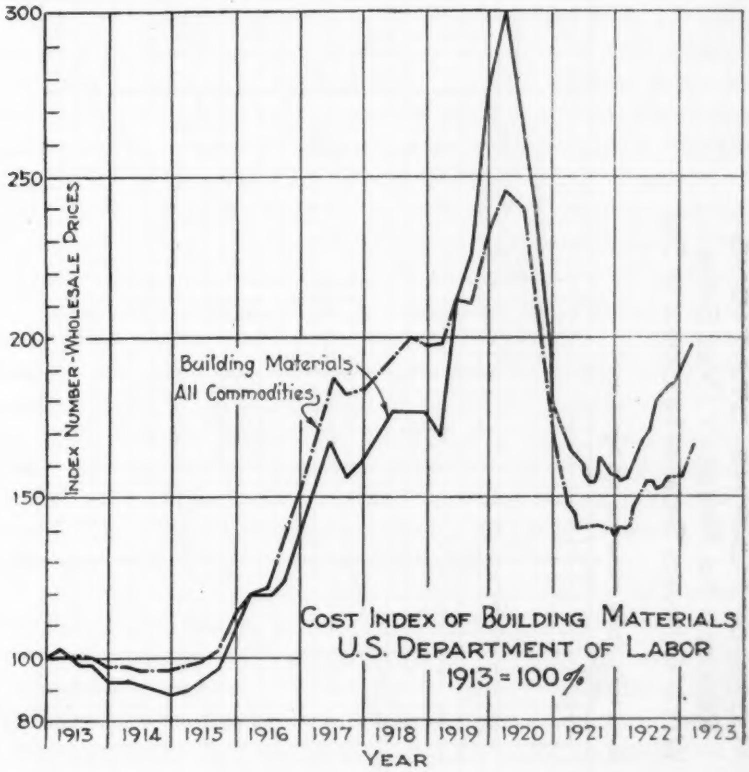

Fig. 10

are high, labor is scarce and its efficiency decreases, therefore tending to make labor cost more nearly fluctuate with the prices of materials. Apparently the assumption made regarding labor does not seriously affect the comparisons of cost for the unit prices appear to line up very well in the comparison of buildings as noted in figure 10.

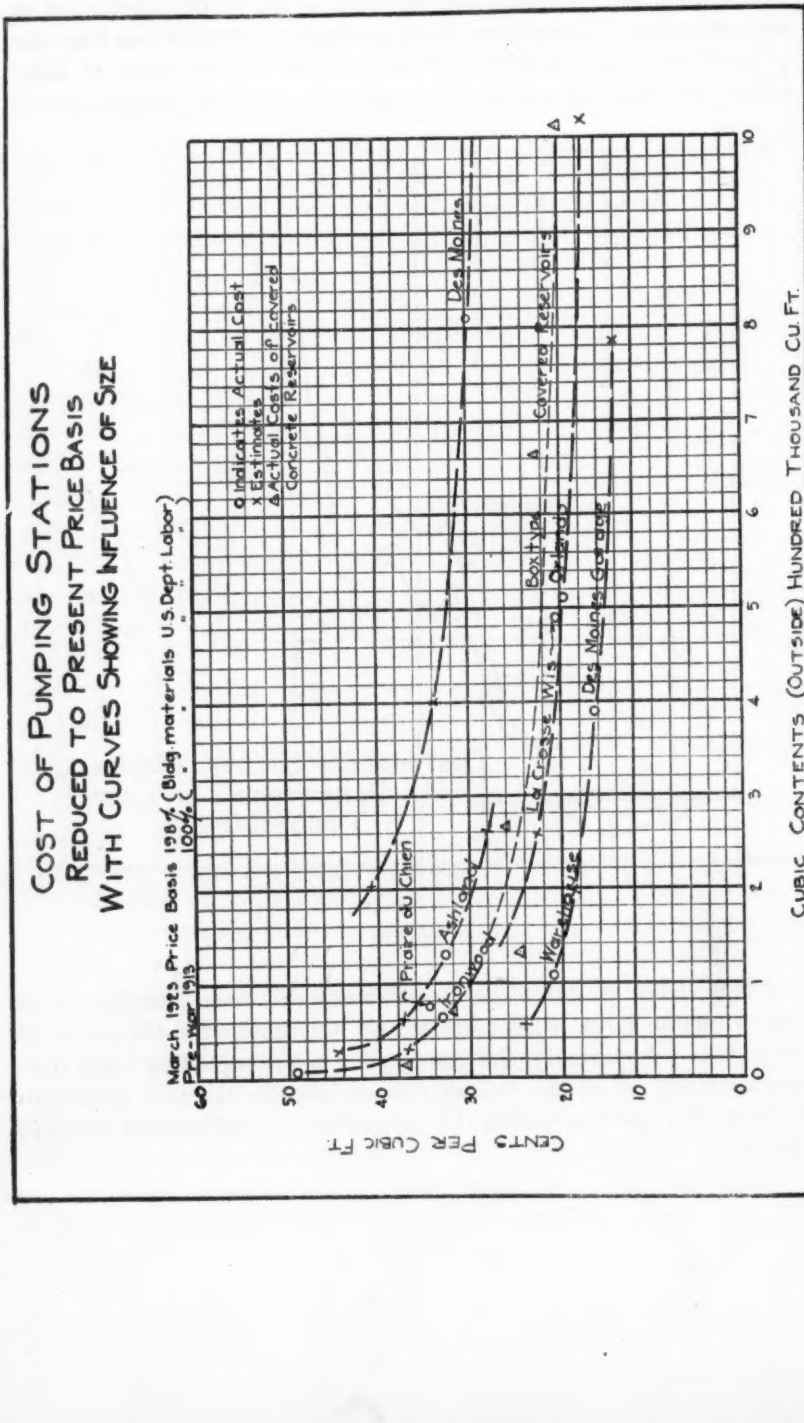
COST OF PUMPING STATIONS
REDUCED TO PRESENT PRICE BASIS
WITH CURVES SHOWING INFLUENCE OF SIZE
March 1923 Price Basis 198% (Bldg. materials U.S. Dept. Labor)
Pre-war 1913 100% (" " ")
o Indicates Actual Cost
x Estimates
Δ Actual Costs of Covered Concrete Reservoirs
Prairie du Chien
Ashland
Kenwood
Des Moines
Box type
Covered Reservoirs
La Crosse Wis.
Orlando
Warehouse
Des Moines Garage
CENTS PER CUBIC FT.
CUBIC CONTENTS (OUTSIDE) HUNDRED THOUSAND CU. FT.
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10

FIG. 11

COMPARISON OF COSTS

In comparing the cost of buildings there are innumerable factors that might be considered. Pumping stations, however, are generally similar in type and vary principally in dimensions and in the degree of finish.

Figure 11 shows diagrammatically the contract price per cubic foot reduced to the present price basis and platted with reference to the cubic contents of the buildings. On this diagram a line has been drawn through each contract price which represents the approximate variation in cost for that particular type of building if increased or decreased in horizontal dimensions and hence cubic contents. It will be noted that in a number of cases these lines covering contracts for similar buildings, large and small, merge into one another. These price lines have been computed on the theory that the costs of roofs and floors vary directly as to area and that the costs of walls increase 43 per cent in doubling the area or decrease 14 per cent when the area is cut in half. These proportions hold only for perfect squares but the difference is small for an ordinary rectangular building. Miscellaneous details such as plumbing and heating are considered to vary directly with cubic contents. Upon the above basis the cost per cubic foot of an ordinary pumping station is decreased about 14 per cent in doubling its contents and it is increased about 13 per cent when its contents are cut in half.

It has been noted that the cost of box type reinforced concrete reservoirs follows closely the cost of moderate priced buildings. As the reservoir structures often accompany the pumping station the unit costs of a number of reservoirs are platted upon the diagram varying in size from large to quite small. These reservoirs are all of the same type. The prices indicated are based on cubic feet of water contained and include all costs except pipe connections.

ARCHITECTURAL COÖPERATION

It would be well if all engineers would utilize the services of an architect in the planning of conspicuous engineering works. A good architect possesses a knowledge of orderly arrangement, and the selection and grouping of materials, not possessed by most engineers. On many classes of structure the architect should be and is the master builder, and the engineer is properly a subordinate. Upon such special structures as water works buildings, the engineer must be the

master builder, but he is wise if he utilizes fully the services of one skilled in architectural design. This must be done by coöperation, the engineering plans and the architectural plans should be worked out together step by step, as a unit.

The water works manager should not ignore public approval relating to his work and his plant. Self-respect engenders respect from others. Capable operators say that employees take better care of their machinery and are more contented when working in attractive surroundings. A good plant is an important element of good service. The time has come when water works designers can safely plan for the future and build for permanence.

LEAKAGE AND UNACCOUNTED FOR WATER[1]

By J. N. Chester and E. E. Bankson[2]

PURPOSE AND GENERAL IMPRESSION

The intention of this paper is to open the discussion on the subject by recalling conclusions from other discussions and by relating some experiences in this connection. Our feeling that the subject is worthy of discussion is based on our experience, which points to a wide variation in the minds of water works men generally as to the actual or permissible amount of unaccounted for water chargeable to different divisions of the system.

In Engineering Record, February, 1912, we are informed that Mr. Bradbury mailed a questionnaire relating to leakage from water mains to sixty-six water works superintendents of Ohio. Twelve of those replying had no views on the subject of permissible leakage; another considered 500 gallons permissible per mile on 6 inch pipe; one said 44 gallons; another 1 gallon; all others considered that no leakage is allowable.

General confidence in the tightness of the pipe system, Mr. Bradbury says, is probably typical of the judgment of a great majority of those having charge of this class of work, and we have found the management of certain of our large cities having no definite idea as to what figures should apply to unaccounted for water.

LOSSES AS PERCENTAGE OF PUMPAGE

While a few water works officials may think of these losses in terms of the component parts that make up the total loss, it is probable that the average superintendent would think of the quantity or percentage which represents the difference between the pumpage and the ultimate delivery, or between the inflow at source and outflow at the spigot, as indicated by the meters.

[1] Presented before the Superintendents' Session, Detroit Convention, May 25, 1923.

[2] Of the J. N. Chester Engineers, Pittsburgh, Pa.

The Committee on Meter Rates of the New England Water Works Association reported in 1916 on Waste of Unaccounted For Water. On page 458 of December issue of the Journal of the New England Water Works Association, we find the result that for twenty-nine metered systems "*the water not accounted for averaged 27 per cent of the total output,*" and on page 459 they convert that same loss into 94 gallons daily for each ⅝ inch meter unit.

In the City of Pittsburgh rate case, our computations were based on a total unaccounted for water equal to 33 ⅓ per cent of the pumpage, and this is the figure also used in our general practice, unless the available data applying to that particular plant will justify otherwise. Percentages from actual tests within our experience might be noted as in table 1 together with certain published figures.

TABLE 1

Total unaccounted for water

In percentage

Norfolk, Va.	38.2	Exclusive of pump slippage
Knoxville, Tenn.	37.8	Exclusive of pump slippage.
*Kensington Water Co.	29.3	Inclusive of pump slippage
*Ellwood Water Co., less than	19.0	Inclusive of pump slippage
Published figures may be quoted as follows:		
Milwaukee, Wis.	25.27	Inclusive of pump slippage
Detroit Mich.	27.5	Slippage not stated
New Bedford, Mass.	23.0	Slippage not stated

* A large percentage of the pumpage was taken by one factory.

These figures give some idea of averages, but the New England Committee states that the figure applying to the plants studied by that committee, ranges from 12 to 49 per cent. The maximum, of course, may be 100 per cent, as was the case at White Sulphur Springs, W. Va., where we were called in for a pitometer survey in connection with the 12 mile pipe line for the water supply to the Greenbrier and White Sulphur Springs Hotels. The minimum might approach zero percentage, as indicated by Mr. Bradbury in the Engineering Record of February, 1912, for Grandview Heights, Ohio, in 1911.

An arrangement was made by this village to purchase filtered water from the Columbus Water Works. After an interval of about two months, the master meter and all individual meters were read, leaving a quantity unaccounted for of 100 cubic feet, or 2.3 gallons per day per mile, although Mr. Bradbury has since stated that, for

the first two years after this system was put in operation, the quantity of water sold through individual meters exceeded the quantity recorded by the master meter (as he remembered, about 25 per cent), undoubtedly caused by slippage of the master meter.

SOURCES OF UNACCOUNTED FOR WATER

The New England Committee report on waste mentions certain sources of losses:

1. Leakage from mains in the streets.
2. Leakage from the service pipes between the mains and the meters.
3. Under-registration of meters (slippage).
4. Water used for various purposes, not registered or estimated, as, for instance, water used for flushing sewers.

And we would say that pump slippage should head this list, if it is to correspond with some of the percentages here shown.

TABLE 2

Standards for cast iron pipe leakage

ENGINEER	LOCATION	SPECIFIED PER INCH MILE	TEST RESULT PER INCH MILE
C. F. Loweth	Statement A. S. C. E.	60–80	
E. G. Bradbury	Proposed N. E. W. W. Assoc.	100	
W. D. Gerber	Statement Ill. W. S. Assoc.	167	
F. A. Barbour	Akron—86 tests	200	83.4
F. A. Barbour	Akron—38 tests	200	61.7
New York Acqueduct	Specifications	240*	
J. H. Gregory	Columbus (3.2 miles)	500+	422
Dexter Brackett	Boston (51.5 miles)		466

* Two gallons per foot of lead joint.

No attempt was made by the Committee to segregate the percentage or amount of any item of loss except to make the statement that "It is the Committee's belief that under-registration of meters forms a substantial part of the total loss in the systems where other sources are carefully watched."

Many engineers do not possess the optimism, regarding street main losses, as expressed in the forgoing statement of the New England Committee; but it is true that perfection, in leakage from street mains, may be obtained only by constant effort, careful work or rigid specifications enforced. That views on this subject differ greatly is to be seen in figures tabulated from Mr. Bradbury's paper before the New England Association in 1914 (table 2).

This leakage at time of test, however, does not tell the story for conditions after the system has been in service for perhaps twenty-five years. The general run of joints may have tightened, or closed up, and concentrated leaks may have appeared from various causes. It is these larger leaks that require the vigilance of the water works man with leak finders, geophone and pitometer and some times only a Sherlock disposition. We had a case at one of our own plants where a $1\frac{1}{4}$ inch pipe had been running full flow for many months.

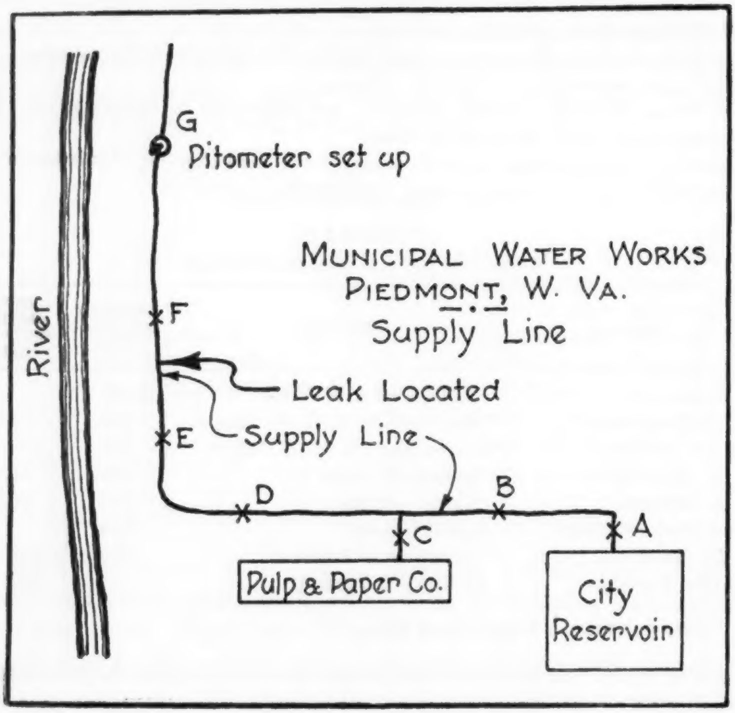

FIG. 1

We have found that a combination of the pitometer and geophone can produce most surprising results in finding leaks when in the hands of an experienced man. The writer would feel, that he had done a great service toward the progress of economy if the "bugaboo" about pitometer surveys could be dispelled. There is many a water works system where the serious leaks may be discovered in one or two nights work with the pitometer, and even the larger systems require only a correspondingly short period of time to eliminate the major troubles.

Our experience at Piedmont might be used to illustrate the principle of the most simple case which may be described by use of figure 1, where the supply line is shown coming from the gravity source to the City reservoir, with very few services on the supply line previous to its entrance to the reservoir; the service of the Pulp and Paper Company being the only one here shown.

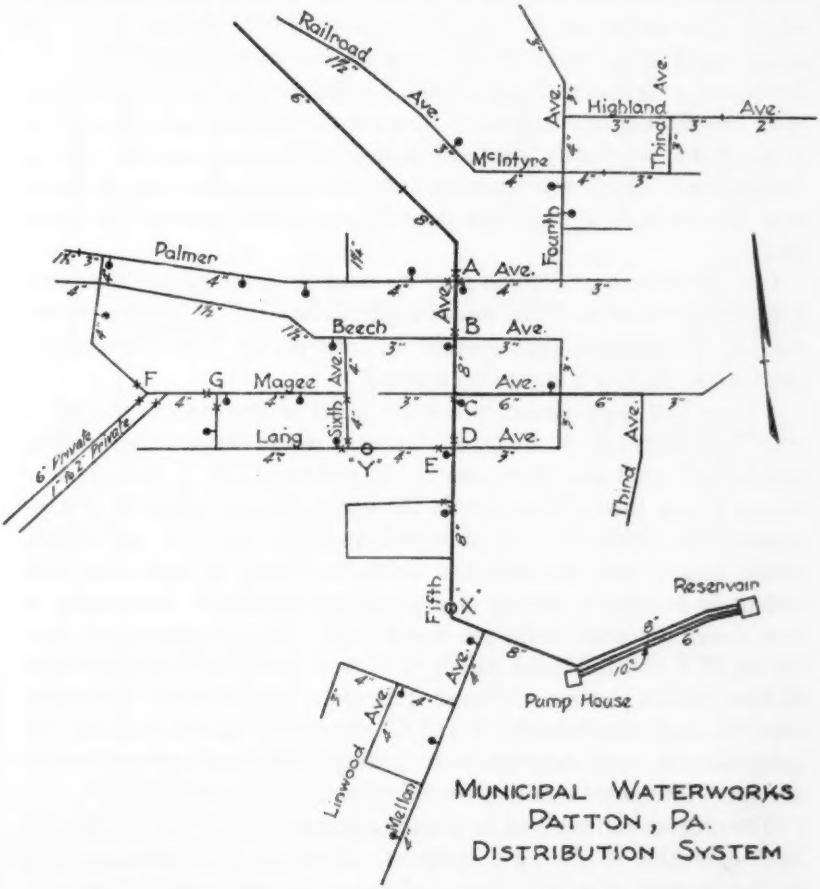

FIG. 2

For some years the Paper Company has been looked upon as the culprit who was stealing water from the City's supply lines and at some times the feeling was very bitter against them. Our suggestion that "the pitometer would produce the evidence" brought forth the response that they were positive there were no leaks in the line be-

cause they had carefully watched that feature and, from experience, they had found that the leaks always readily came to the surface any way. The approximate location of valves are shown at *A*, *B*, *C*, *D*, *E* and *F* and the pitometer set-up shown at *G*, where it was determined that practically the full supply was passing.

After the pitometer was in place and ready for operation, the valves were closed in succession from *A* to *F* at time of low flow in the night. No reduction in the flow passing the pitometer at *G* was noted until after valve *F* had been closed which means that the leakage was between *E* and *F*, and by the process of a few set-ups, with the pitometer run from *F* towards *E*, together with the use of a geophone, we finally located the leak which was creating all the trouble and which was running into the river below the ordinary flow line in such a way that it had never been detected all these years.

Our experience at Patton may be used to demonstrate the more complicated case, and this would apply to any size of system by the process of breaking that system up into parts. The distribution system for Patton is shown on figure 2.

Valves had been closed in certain parts of the system in such a way that valves *A*, *B*, *C*, *D*, *E*, *F* and *G* would serve as controlling points and with the pitometer at *X*, valves *A*, *B*, *C* and *D* were closed at the time of low flow in the night and no reduction of flow passing the pitometer was indicated until the valve *D* was closed, which meant that the leak was between *C* and *D* and was later definitely located by means of a geophone and again when valve *E* was closed a second reduction was noted. The pitometer was then set up at *Y* and the three valves at *F* were closed with no reduction in flow, but on closing *G* a decided decrease was observed, indicating that the leak was between *F* and *G*, which was also located by the geophone, in each case the leak flowing away underground unobserved. Pitometer readings for this case are shown on figure 3.

The process as described for Patton required only a few minutes for each operation of closing a series of valves and then opening them in the reverse order as a means of using the increases in flow as a check on the original decreases in flow during the operation of closing the valves.

Several examples like this could be cited where only two or three nights have been consumed in finding the serious leaks and the superintendents of some of these plants now swear by the geophone

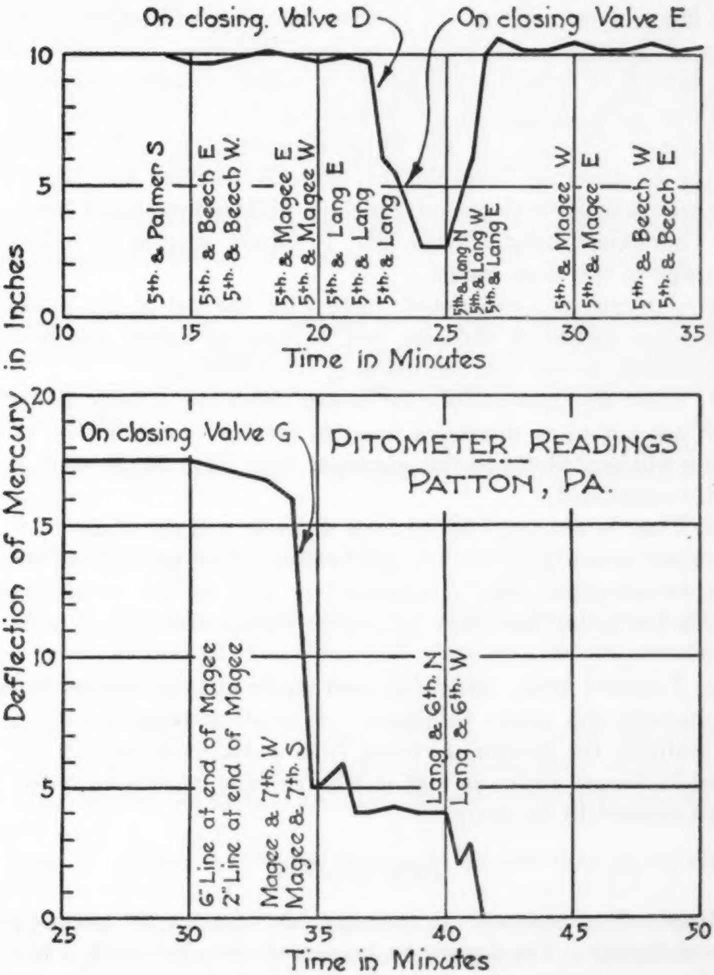

FIG. 3

and refuse to be without one, such as at Etna, Edgeworth and West Newton, Pa. Our survey at Etna, Pa., of about three nights work, discovered two or three major leaks which reduced the electric pumping bill from about \$500 to \$350 per month.

UNDER REGISTRATION OF METERS (OR SLIPPAGE)

The New England Committee on meter rates has stated that "there are few meters in use at the present time that will register a steady flow of as little as 100 gallons per day" and that, if at least half of the meters in service could handle the daily quantity passing at a uniform rate, instead of the fluctuating rate, it would all pass as leakage or slippage. In the Milwaukee report for 1912, appearing in the Engineering News-Record, there is assumed the figure of 3 per cent as under registration of meters, while as mentioned heretofore for Grandview Heights Ohio, Mr. Bradbury suggest 25 percent as slippage of the large meter.

We, in our own experience, have with the use of the pitometer and other means of checking and calibrating meter measurement established, to our own satisfaction, the following:

1. There are types of detector meters, especially of large diameters, that are not to be depended upon to measure consumption and so doing will contribute to the consumer from 12 to 90 per cent of the water consumed.

2. That in waters prone to form deposits and especially of a soft or mushy consistency meters may be stopped altogether and the entire consumption pass unregistered or due to the accumulations within the meter there may be an over registration from 5 to 30 per cent.

3. Frequent tests, calibration and repair of large meters increase enormously the return therefrom. It is not unusual by such means to multiply the revenue received from a consumer by two and we have had cases where as high as 500 per cent increase in return has been effected by so doing.

DISCUSSION

Henry P. Bohmann: I am sorry Mr. Chester did not use more recent figures. The figures he presented were for 1912, I believe. Beginning in 1912 we made an effort to control avoidable waste and started to estimate the amount of water used for domestic, industrial, and municipal use, and also show the amount of water unaccounted for. Since then we have brought this figure down as low as 11 per cent. We have assumed 5 per cent slippage of pumps and 3 per cent under-registration of meters throughout the entire period of ten years. It is true very many large meters under-register more than three per

cent, but that is an overall estimate. All large meters we test once a year. The small meters we do not test because the result would hardly justify the expense, considering the small revenue received from small meters. We figure that within the period the meter will come in the shop for some reason or other, either through frost or perhaps because registration has stopped, or for some other reason. The figures Mr. Chester presented are undoubtedly correct for that year, but we brought the figures down considerably.

John N. Chester: How do you know you brought them down, if you assumed 5 per cent slippage.

Henry P. Bohmann: Because we adopted the same method all the way through of estimating the amount of water that is unmetered, the figures we show for unmetered water can be substantiated; it is not a mere guess.

John N. Chester: Did you compile the total registration of all meters?

Henry P. Bohmann: Certainly.

John N. Chester: And then you added your estimate of the unmetered water and compared that with your actual pump displacement?

Henry P. Bohmann: Yes sir. First, we deduct 5 per cent for slippage of pumps to show the amount of water that actually went into the distribution system and then there is the metered water.

John N. Chester: Which you again correct with 3 per cent.

Henry P. Bohmann: We allow 3 per cent for under registration of meters, since everyone knows that meters do under-register.

John N. Chester: If you had a master meter at your station and cut out pump slippage, that would make it comparable with some of the figures here?

Henry P. Bohmann: We cannot do that because several of our pumps discharge into one discharge main and sometimes run singly and sometimes double, and are equipped only with Venturi meter.

John N. Chester: What is your unaccounted water when you simply equate your meter consumption, meter registration, against your master meter registration? What then is the difference?

Henry P. Bohmann: As I told you, we have had it down as low as 7 per cent unaccounted for.

John N. Chester: But you first deduct those other percentages?

Henry P. Bohmann: First of all we deduct 5 per cent from the displacement of the plungers of the pumps to take care of slippage. We have 5 discharge mains with Venturi meters, but have only one pump that discharges into a separate discharge main, consequently it is not practical to do otherwise.

John N. Chester: But you are talking about pump slippage; let us leave that out; you say all your discharge mains have master meters?

Henry P. Bohmann: Not the mains, they have a Venturi tube, with a recorder, but we have not a separate discharge main with a separate discharge recorder for each pump, that is the reason why we use the Venturi, merely as a check against plunger displacement.

John N. Chester: You are talking about pump slippage, and I am trying to get the unrecorded water, leaving out pump slippage.

Henry P. Bohmann: In Chicago they estimate pump slippage at 15 per cent.

John N. Chester: The water that passes your master meter, let it be assumed as the amount pumped; how do your small meters add up as compared with the results of your master meters?

Henry P. Bohmann: You have got to add to that the amount of water unmetered.

John N. Chester: All right, do that.

HENRY P. BOHMANN: You want to eliminate the slippage entirely?

JOHN N. CHESTER: Oh, yes, I want to forget it.

HENRY P. BOHMANN: Then we will say about 15 per cent is unaccounted for, but I do not think that is fair, because there is certainly some slippage in every station, and if the stations throughout the country would have but 5 per cent, they would make a better showing than at the present time. What is the use of trying to account for something that is not going into your distribution system?

JOHN N. CHESTER: The master meters are between the pumps and the city, are they not?

HENRY P. BOHMANN: We only use our Venturi meters as a check against displacement and then we deduct 5 per cent for correction.

A. S. HOLWAY: Four years ago, we checked up our meter consumption as 44 per cent of the pumpage. We have been able to reduce the unaccounted for water to such a point that our total metered water which we sell is 79 per cent of the water which leaves the pumping station. We have found that our greatest losses come from three sources. We had some illegal consumers, we had one 8 inch illegal connection, one 3 inch connection and a 1 inch meter by-pass. We found quite a few leaking flush tanks in the sewer system, but our greatest loss was due to poorly kept up meters, and I think that that is a thing that is very frequently overlooked in most systems, and that is the greatest cause for unaccounted for water.

W. S. CRAMER: We pride ourselves that we have been for twenty years 100 per cent metered. I mean that we sell no water except through a meter; we do not allow the use of fire hydrants by contractors or any other connection except through a meter, and we have a good clay soil and the water comes to the surface; at least we think it does. We have all cast iron mains and lead services, and we pride ourselves that we should be free from leaks, but in checking

back against our meters and against our pumps, we could not get an accounting for the water through the pumps; our pumps were in fairly good condition and were tested as much as pumps could be tested by blocking the piston and testing them that way. We put a meter on our discharge, and immediately we got a perfect check, and a survey showed a loss of 740,000 gallons in twenty-four hours on a system we thought was in first class shape. Almost all the leakage was water that was going to waste through sewers. There had been an intensive sewer campaign and leaks were going through the sewers and not showing on the surface, so there are very few of you who can rest on the supposition that you have no leaks or are accounting for the water, unless you are actually going over the system and finding out whether you have those leaks. We stopped a leakage of about 20 per cent of the water pumped.

RECARBONIZATION OF SOFTENED WATER[1]

By Nicholas S. Hill, Jr.[2]

For municipal purposes it is frequently desirable to filter water as well as to soften it, and it is not uncommon in municipal plants to deliver a hard water after treatment by the lime and soda process to mechanical filters where the water is filtered in the ordinary way. Except that where softening is desirable, larger sedimentation basins are generally used and facilities must be provided for storing the lime and soda and mixing them with the water, the combined softening and filtering plant is substantially the same as the ordinary filtration plant. Where softening precedes filtration, however, difficulties arise, one of which results from the deposition of the calcium and magnesium carbonates, which are carried to the filters with the settled water, on the grains of the filter sand and in the filter piping and mains. As a result of the deposition of the carbonates on the sand grains they become heavily coated and their effective size is much increased. The experience at Columbus, Ohio, Grand Rapids, Michigan, McKeesport, Pennsylvania, and other places, indicates that the sand in the filter beds becomes so coarse as to make it inefficient at times for filtering turbid water, but this is not the only difficulty. The calcined grains cement themselves together, forming hard lumps which become quite large in size and are so hard that they have to be dug out of the filter beds in order to be broken up. This lumping of the sand prevents the wash water from breaking through the sand beds uniformly and, therefore, causes a high rate of filtration in the free parts of the filter beds. Under such conditions it is necessary to add excessive amounts of alum to remove turbidity, which increases the cost of treatment.

The presence of the carbonate of lime also interferes with the proper operation of the filter underdrains.

The ideal softened water should contain neither permanent hardness nor temporary hardness. From an operating viewpoint it should

[1] Presented before the Chemical and Bacteriological Section, Detroit Convention, May 25, 1923.

[2] Consulting Engineer, New York, N. Y.

be entirely free from caustic or carbonate alkalinity, but this result is difficult, if not impossible, to achieve with the lime and soda process, and due to limitations in the accuracy of applying lime and soda solutions and the vagaries of the re-actions in water softening, caustic water is often delivered to the filtration plant from the settling basins, particularly when it is attempted to keep the hardness of the water to be softened at the lowest possible limit. On the other hand, the application of a slight excess of lime frequently insures a better degree of softening, provided the causticity produced by the introduction of an excess of lime may be subsequently removed.

A caustic water which is produced by an excess of lime hydrate, without further treatment, leads to troubles with after-precipitation and to complaints from consumers due to its objectionable taste.

Much trouble has been experienced in combined water softening and filtration plants from the presence of the carbonates of lime and magnesia and hydrate of lime in the effluent from the settling basins, and much has been written and said upon the subject.

Attempts in the past to remove the lime and magnesium carbonates have been devoted chiefly to increasing the size of the sedimentation basins by giving them a capacity equal to from ten to twenty hours detention to allow time for the re-action between the lime and bicarbonates in the water as well as time for the complete precipitation of the lime carbonate in the softened water, thereby reducing the deposits of the calcium carbonate on the grains of the filter sand and in the filter piping and mains. Such basins, however, have served as a palliative rather than a remedy, and these large basins are expensive to construct, particularly where land values are high.

Results at Columbus, Ohio, from twelve thousand determinations during the past eleven years indicate that the period of re-action between the softening chemicals and the calcium and magnesium salts is short. Mr. Charles P. Hoover, Chemist in Charge of this plant states in *The City Bulletin*, the official publication of the City of Columbus, of April 15, 1923, that 90 per cent of the re-action accomplished takes place in the mixing tanks, 3 per cent in the fifteen hours through the settling basins, and 7 per cent in passing through the filters. The average hardness of the Scioto River water at Columbus is 275 parts per million, of the water entering the settling basins 119 parts per million, at the outlet of the settling basins 113 parts per million, and of the filtered water 101 parts per million. As he states, these figures are startling because they indicate that large settling

basins are not necessary for the proper chemical re-actions at least, as has always been supposed, and certainly they are not always effective in sedimenting the lime carbonate when it is in a collodial state.

At some plants roughing filters made of excelsior or other materials have been used to remove the carbonates of lime after the water leaves the settling basins and before it passes on to the filters, but this method has not proved successful in operation.

The first investigations towards working out a practical solution of the difficulties resulting from the presence of lime carbonate in the effluent of the settling basins were made by Mr. Charles P. Hoover at the Columbus plant, so far as I can recall at this writing. The first method which suggested itself to him was to carbonate the water with CO_2, and he experimented with a number of ways by which carbon dioxide might be produced, among which were:

1. Burning the lime sludge from the settling basins, producing lime and CO_2.
2. Treating the lime sludge from the settling basins with sulphuric acid, producing calcium sulphate and CO_2.
3. Calcining sodium bicarbonate, producing sodium carbonate and CO_2.
4. Treating soda ash with sulphuric acid, producing sulphate and CO_2; then roasting the sodium sulphate in a furnace with slack coal and limestone, producing sodium carbonate, which could be used in softening.

By carbonating the water the insoluble carbonates are converted into the soluble bicarbonates. If the water is caustic the CO_2 will re-act with the caustic or hydrate of lime, producing soluble bicarbonates of lime. In other words, by using CO_2 the normal carbonate alkalinity and the caustic alkalinity are converted to bicarbonate alkalinity in solution and there is no reduction in the hardness of the water which leaves the settling basin.

It would be a desirable thing if an inexpensive and easily handled re-agent could be found which would not only convert the carbonates and hydrates into soluble bicarbonates but precipitate all, or even a large portion, of these as well, for then not only would the stabilizing effects desired be accomplished but additional softening as well. Various re-agents have been tried for this purpose. Boric, oxalic, tartaric and phosphoric acid were experimented with at the Columbus plant, and there the final conclusion reached was that as a finishing treatment to lime-softened water phosphoric acid was the best and most economical.

The advantages of using a re-agent of this kind as compared with carbon dioxide are obvious, but the method is expensive and difficult to handle. It was found, however, that when enough phosphoric acid was added to lime-softened water to combine with the caustic alkalinity, and with one-half the normal carbonate of calcium and magnesium, a re-action resulted which produced tri-calcium phosphate, which is insoluble and readily settled from the water and CO_2, which carbonated the remaining quantity of normal carbonates. By this process half of the carbonates are removed, thus reducing the hardness of the water. The balance of the carbonates are carbonated, thus producing a water that is stable.

The first application of carbon dioxide gas to water, which is generated from the burning of coke, subsequent to treatment by the lime and soda softening process, so far as the author knows, was at Owensboro, Kentucky, some years ago. (For description of this plant see this Journal, 1912, page 203). The apparatus employed, however, was very crude and although the results were reported as satisfactory, the use of this gas to eliminate or nullify the ill effects produced by the carbonates of lime and magnesium and lime hydrate seems to have been entirely overlooked.

Nowhere that the author knows of has any attempt been made, prior to the installation of the carbonating plant at Defiance, to provide a workable and controllable means of applying CO_2 to the effluent from the settling basins for the purpose of converting the carbonates of lime and magnesium and lime hydrate in the softened water into the bicarbonates of lime and magnesium.

It is not my purpose to describe the Defiance, Ohio water treatment plant in detail, as a description of it has already been published in this Journal, 1920, page 440.

The average quality of the raw Maumee River water, based upon the average of daily analyses at the Napoleon and Toledo filtration plants as well as analyses at Defiance, and of the softened water at Defiance for the year 1922, is as follows:

	RAW WATER	FILTERED WATER
	p.p.m.	*p.p.m.*
Turbidity	200	0
Color	40	8
Total hardness	230	125
Alkalinity	170	52
Incrustants	60	73
Calcium hardness	172	70
Magnesium hardness	58	55
Bacteria per cubic centimeter at 37°C	400	

From September 1, 1920 to January 15, 1922 both lime and soda were used in the treatment, but since the latter date only lime has been used. In other words, since January 15, 1922, there has been no attempt to reduce the incrustants or permanent hardness but to reduce only the temporary or carbonate hardness. This method of operation has been followed in the interest of economy as it has been found that the removal of the temporary hardness produces a water which is locally satisfactory and that the total hardness may be maintained at an average of about 125 parts per million.

While the above characteristics present the average quality of raw water to be expected, the variations are extreme. Turbidity at times may be as high as 4000. Total hardness is sometimes as high as 350, and the bacterial count at 37°C. reaches several thousand. In view of the variable quality of the water and the constant variation in the amount of chemicals used, it was necessary to design the carbonating plant so that the amount of CO_2 applied could be regulated and a CO_2 recorder is a part of the equipment of the plant. The amount of coke required, however, to treat a million gallons of water at Defiance is less than 100 pounds, so that the cost is nominal, and it was found that it would not be necessary to prevent the application of some excess CO_2.

According to Mr. H. T. Campion, Superintendent at the Defiance plant, the added cost of the carbon dioxide treatment does not exceed \$1.88 per million gallons under the present intermittent method of operating the plant, which naturally increases the amount of coke required per million gallons as it is impossible to prevent the generation of gas in the retort when the softening plant is shut down.

In operation it has been found possible to control the application of CO_2 so that no gas escapes from the surface of the water entering the chamber and hence there is no waste of gas. The amount of CO_2 applied is regulated, so that when the water leaves the plant it has no more than three to five parts per million of free carbonic acid.

For the benefit of those who have not read the description of the plant above referred to, I would say that the carbonating plant at Defiance consists of a retort in which coke, sometimes with an admixture of a small amount of limestone, is burned, giving off CO_2. A seventy-two hour coke has been used for generating the CO_2. This material burns slowly, holds its fire well and has a low sulphur content. An eight hour coke was tried but did not prove as successful as the seventy-two hour coke. The eight hour coke contained at times unburned tar and it is possible that the use of this material caused slight phenol odors in the carbonated water at times. After the gas is generated in the retort it is mixed with air introduced through a valve which opens to the atmosphere and is placed on the pipe which conducts the CO_2 from the retort to the scrubber. The amount of air admitted is controlled at this point and is adjusted so as to regulate the quantity of CO_2 to be applied to the water. The admixture of air and CO_2 gas then passes through the scrubber. The admixture enters the bottom of the scrubber and the water is fed to it at the top. This removes the impurities from the products of combustion. The admixture of gas and air passes from the scrubber through the dryer and from there goes to a chamber, which, for want of a better name, I have called the carbonating chamber. A blower or compressor is installed adjacent to the retort which sucks the air and gas from the retort through the scrubber and drier, and forces the mixture through a 2 inch fibre pipe line to the carbonating chamber. There the admixture of air and CO_2 is delivered to an annular space beneath filtros plates and is allowed to pass up through the filtros plates and the water. When the CO_2 mingles with the water the normal insoluble calcium carbonate is converted into soluble calcium bicarbonate and the calcium hydrate is also converted into soluble calcium bicarbonate. Insoluble magnesium hydrate is also converted into soluble magnesium bicarbonate.

There is a continuous flow of water through the carbonating chamber, the period of detention being about one hour. A series of baffles is provided in this chamber so that the water passes up and down in its travels through the container.

The percentage of carbon dioxide in the mixture of gases applied to the water is not high, varying from 3 to 10 per cent of the total mixture of air and gas to meet the condition of the settled water, the phenolphthalein alkalinity of which varies appreciably. No variation is made in the volume of air and CO_2 sent to the carbonating chamber, but variations in the amount of CO_2 applied are effected by changing the mixture of air and gas. The compressor or blower is run at a uniform speed all the time and a CO_2 recorder has been installed adjacent to the compressor which shows at any time the percentage of CO_2 in the admixture of air and gas delivered to the carbonating chamber.

The regulation of the amount of CO_2 gas to be applied at any time is effected by making hourly tests of water leaving the carbonating chamber with phenolphthalein. If the tests show too great an excess of CO_2 the operator is instructed to reduce the percentage of CO_2 in the mixture of air and gas as indicated by the CO_2 recorder, and if there is no excess of CO_2 the operator is instructed to increase the percentage in the admixture.

From time to time in the past troubles from odors in the Maumee River water have been experienced when the river is low or ice bound, and these odors caused a prejudice to the water by the consumer. The dissolved oxygen in the river water at times is very low. It has been shown above that the percentage of carbon dioxide in the admixture of air and gas delivered to the carbonating chamber varies between 3 and 10 per cent, so that a large proportion of the admixture is air. The aeration which is offered by the passage of the air through the water in the carbonating chamber has a beneficial effect during the occurrence of odors in the raw water. Tests for dissolved oxygen in the raw water and as it leaves the carbonating chamber show a material increase in saturation in the carbonated water at times when the oxygen content of the raw water is low.

At the time the carbonating chamber was designed the author had no precedent by which to go and little definite knowledge of the effect of temperature and other agencies upon the time required for the re-actions desired, and as a precautionary step was very careful to make this chamber sufficiently large to allow ample time for the completion of all chemical re-actions. As a result of the operation of this plant, however, and the promptness with which the re-actions take place, he would install a smaller and simpler carbonating chamber where there was no necessity for combining aeration with carbonation.

One of the interesting features of the plant is that in designing the carbonating chamber precaution was taken for the removal of sludge due to the precipitation of the calcium carbonate by the first

TABLE 1

Results of analyses of water from water treatment plant at Defiance, Ohio

CONSTITUENTS	INLET, SETTLING BASIN		OUTLET, SETTLING BASIN		OUTLET, CARBONATING CHAMBER—CARBONATED WATER		OUTLET, FILTERS—FILTERED WATER	
	Sample 8754 10-23-22	Sample 9421 4-10-23	Sample 8755 10-23-22	Sample 9422 4-10-23	Sample 8756 10-23-22	Sample 9423 4-10-23	Sample 8757 10-23-22	Sample 9424 4-10-23
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Turbidity	48	375	12	13	1	6	0	0
Color	24	43	6	14	6	10	9	8
Total solids	419	687	238	241	241	244	242	250
Suspended solids	65	367	19	9				
Solids in solution	354	320	219	232				
Iron							0.05	0.05
Total hardness as calcium carbonate ($CaCO_3$)	247	218	99	117	120	126	121	129
Lime (Ca) expressed as $CaCO_3$	153	165	67	105	84	111	79	106
Magnesium (Mg) expressed as $CaCO_3$ (by difference)	94	53	32	12	36	15	48	23
Caustic alkalinity expressed as $CaCO_3$	0	0	20	2	0	0	0	0
Normal carbonate alkalinity $CaCO_3$	14	0	16	32	0	0	0	0
Bicarbonate alkalinity $Ca(HCO_3)_2$ expressed as $CaCO_3$	172	163	0	0	50	33	47	35
Free carbonic acid (CO_2)	0	5.3	0	0	0	5.1	1.3	0
pH	8.1	7.7	9.8	9.5	7.85	7.1	7.65	7.8
Chlorides (Cl)	16.9	5.3	16.3	6.5	16.0	6.2	16.0	7.7
Sulphates (SO_3)	66	56	77	73	79	71	75	76

re-action in the conversion of calcium hydrate to calcium bicarbonate when the CO_2 is applied to water which contains caustic lime. In actual operation, however, it has been found that there is practically no deposition of sludge as the re-action takes place so rapidly that

the end product of soluble bicarbonate of lime is at once produced. The provision for the removal of sludge according to the experience at Defiance is, therefore, not necessary.

The author regrets that he is not able to present the results of systematic analyses made to cover a long period of time so that good average results could be presented. Reports of the daily operation of the plant, however, have shown that it has proved efficient and economical.

Table 1 gives the results of analyses made in the author's laboratory of samples taken at different points in the softening and filtration process. It shows that the caustic alkalinity and normal carbonate alkalinity, which are present at the outlet of the settling basin, are entirely removed in the carbonating chamber and are converted into soluble bicarbonate alkalinity.

Further reference to this table also indicates that the alkalinity after leaving the carbonating chamber is somewhat higher than before it enters it. It would be natural to expect a reduction of alkalinity in the carbonating chamber as the second application of aluminum sulphate is made at this point. Taking the normal reduction due to the second application of sulphate of aluminum into consideration there is an appreciable increase in the alkalinity of the water after it leaves the settling basin and passes through the carbonating chamber. The increase in alkalinity probably accounts for the increase in total hardness, although the number of analyses available is not sufficient to make this statement definite. In fact, it would take a long run of analyses for the purpose of getting proper averages to enable one to draw deductions as to just what changes take place. The important thing is that normal calcium carbonate and magnesium hydrate are stabilized by conversion into the soluble bicarbonate hardness.

The only disadvantage of carbonating the water is that there is no reduction in the total hardness, and probably a slight increase in total hardness, after the water leaves the settling basin, but when it is remembered that it not only removes the lime carbonate which causes so many operating troubles in filter beds, but also the causticity, thereby enabling the operator to apply an excess of lime when it is advisable or economical to do so, its advantages outweigh its disadvantages. Its simplicity, easy control and small cost weigh heavily against the adoption of other methods which will somewhat reduce the hardness of the water after it leaves the settling basin but which involve appreciable expense and difficulty in application.

It has been found that, by regulating the CO_2 applied to the carbonating chamber, so that at all times there is some CO_2 present in the carbonated water, the flat taste which is noticeable in most lime-softened waters has been removed.

By the use of the process it is possible to reduce the period of detention in the sedimentation basin from that in the ordinary settling basin of from ten to fifteen to six hours or less.

It is estimated that the cost of the CO_2 plant, including fixed charges and operating expenses, does not exceed the interest on the cost of larger basins which would have to be built if this process is not installed, and the experience at Defiance has indicated that the carbonating process is far more effective than the introduction of larger basins.

The re-actions which occur in the carbonating chamber may be stated as follows: When lime hydrate in the settled water is treated with carbon dioxide gas the lime hydrate is converted to calcium carbonate and then a further re-action between the calcium carbonate and carbon dioxide converts the calcium carbonate into calcium bicarbonate. The re-actions taking place in the carbonating chamber may be expressed as follows:

Calcium hydrate	+	Carbon dioxide	=	Calcium carbonate	+	Water
$Ca(OH)_2$	+	CO_2	=	$CaO \cdot CO_2$	+	H_2O
				$(CaCO_3)$		

Calcium carbonate	+	Carbon dioxide	+	Water	=	Calcium bicarbonate
$CaOCO_2$	+	CO_2	+	H_2O	=	$CaO_2\ CO_2H_2O$
						$(Ca(HCO_3)_2)$

Magnesium carbonate is much more soluble in water than is calcium carbonate and the precipitate of magnesium which goes over from the settling basins is usually in the form of magnesium hydrate. The re-action which takes place in the carbonating chamber so far as the magnesium salts are concerned may be expressed as follows:

Magnesium hydrate	+	Carbon dioxide	=	Magnesium carbonate	+	Water
$Mg\ (OH)_2$	+	CO_2	=	$MgO \cdot CO_2$	+	H_2O
				$MgCO_3$		

Magnesium carbonate	+	Carbon dioxide	+	Water	=	Magnesium bicarbonate
$MgO \cdot CO_2$	+	CO_2	+	H_2O	=	$MgO \cdot 2CO_2 \cdot H_2O$
						$Mg(HCO_3)_2$

The operations of the plant, which has now been in service about twenty-one months, have been watched by the author with some interest. Samples of the sand from the filter beds have been collected

and brought to his laboratory on two occasions, in October of 1922 after the plant had been in operation a little over a year, and in April of 1923, when the plant had been in operation about twenty-one months. Mechanical and chemical analyses were made of the original sand used in the filters as well as of samples from each filter bed for the purpose of ascertaining whether there was any appreciable change in the effective size and uniformity coefficient of the sand as a result of actual operations, as well as to ascertain the quality of the coating on the sand grains if they had become coated.

The results of the mechanical analyses of the original sand as compared with samples taken from each of the filter beds in October of 1922 and in April of 1923 compared with similar analyses of sand taken from the Grand Rapids plant after service for about the same period of time are given in table 2. The samples taken on October, 1922 after the Defiance plant had been in operation a little over a year indicate that the effective size of the sand had increased from an average of 0.43 to 0.49 and that the uniformity coefficient had dropped from an average of 1.51 to 1.27. The increase in size at Grand Rapids for a similar period was from 0.35 to 0.42 and in the uniformity coefficient from 1.25 to 1.33.

TABLE 2

Mechanical analysis of sand samples

	Defiance original sand—average three samples, 5-16-21	Defiance filter bed sand—average four samples, 10-11-22, in use 15 months	Defiance filter bed sand—average four samples, 4-11-23 in use 21 months	Grand Rapids original sand	Grand Rapids, in use 2 months	Grand Rapids, in use 22 months
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Effective size	0.43	0.49	0.49	0.35	0.42	0.51
60 per cent finer than	0.63	0.62	0.62			
Uniformity coefficient	1.51	1.27	1.26	1.25	1.33	1.22

The increase in effective size and reduction in uniformity coefficient at Defiance is in the judgment of the author no greater than would be expected from the continued washing of the filters in an ordinary filtration plant.

Mechanical analyses made on the samples collected at the Defiance filter plant in April, 1923 show an effective size of 0.49 as compared with 0.49 for the samples from the Defiance filter beds taken in October, 1922, or exactly the same.

The effective size of the sand from the Grand Rapids plant taken in August, 1914, after it had been in operation about twenty-two months, had increased from 0.35 to 0.51, an increase of 16 points as compared with 6 points for the same period at Defiance.

The uniformity coefficient of the samples collected at Defiance in April, 1923 was 1.26 as compared with 1.27 for the October, 1922 samples.

These results compared with the Grand Rapids results are interesting and seem to indicate that the Defiance sand had reached its natural grading as a result of the continued washing in October, 1922, and no appreciable change has occurred in the last six months either in uniformity coefficient or effective size.

Further to ascertain definitely whether the accretions on the filter bed sand were appreciable, 100 grams of this sand were treated with 1-1 cold hydrochloric acid. The acid was then filtered off, the sand washed, dried, and a mechanical analysis of it then made for comparison with the sand as it was removed from the filter beds, after twenty-one months use, as well as with the original sand. The comparison follows:

	UNTREATED FILTER BED SAND	TREATED FILTER BED SAND	ORIGINAL SAND
(1)	(2)	(3)	(4)
Effective size	0.49	0.48	0.43
60 per cent finer than	0.62	0.62	0.63
Uniformity coefficient	1.26	1.29	1.51

This test confirms the author's belief that the slight increase in the effective size and reduction of the uniformity coefficient of the used sand are due to the grading which follows the continued washing of sand in filter beds.

While there was no visible coating on the surface of the sand grains taken from the filter beds, the author thought it was desirable to make a chemical analysis to ascertain if possible what the nature of the coating was, if any. Twenty gram portions of the filter bed sand were treated with 1-1 hydrochloric acid in the cold. The sand was then filtered off and washed with water. This treatment has no effect on the sand itself, but dissolves practically all the aluminum, calcium or magnesium compounds that might stick to the surface of the sand grains. Samples of the original sand before it was used in the filter beds were taken as a control and treated in the same way.

The filtrate was evaporated to dryness in platinum dishes and the residue weighed. It was ignited and weighed again. It was then dissolved in acid and a chemical analysis made to determine the composition of the fixed residue of all the samples. The results of these analyses are shown in table 3.

The samples of the original sand showed no effervescence when the hydrochloric acid was added, and only one of the sands removed from the filter beds showed effervescence, and in this case it was only in a spot or two. This indicated how free from carbonates the sand from the filter beds was.

The total acid soluble residue as dissolved by the 1-1 hydrochloric acid in the four samples of filter bed sand which were treated varied

TABLE 3

Chemical analysis of sand from Defiance, Ohio, filtration plant (data in per cent)

CONSTITUENTS	ORIGINAL SAND, SAMPLE NO. 292	FILTER NO. 1, SAMPLE NO. 288	FILTER NO. 2, SAMPLE NO. 289	FILTER NO. 3, SAMPLE NO. 290	FILTER NO. 4, SAMPLE NO. 291	AVERAGE, NO. 288 TO NO. 291
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total residue	0.038	0.87	0.78	0.59	0.65	0.72
Organic and volatile	0.025	0.42	0.40	0.31	0.34	0.37
Fixed residue	0.013	0.45	0.38	0.28	0.31	0.35
SiO_2	0.002	0.115	0.085	0.070	0.062	0.083
Fe_2O_3 and Al_2O_3	0.005	0.194	0.142	0.105	0.134	0.144
CaO	0.002	0.028	0.043	0.017	0.035	0.031
MgO	0.001	0.009	0.007	0.008	0.009	0.008
Undetermined	0.003	0.104	0.103	0.080	0.070	0.084

from 0.59 to 0.87 per cent by weight of the sample of the sand taken, with an average of 0.72 per cent. The average fixed residue on the filter sample was 0.35 per cent. The control or the original sand showed a total acid soluble residue of 0.038 and a fixed residue of 0.013 per cent.

Similar analyses of sand taken from the Grand Rapids filter bed after twenty-two months of use as compared with twenty-one months of use at Defiance showed an increase in the acid soluble residue of from 6.5 in the original sand to 45.2 per cent in the filter bed sand, an increase of 38.7 as compared with an increase for the same period of 0.7 per cent at Defiance.

The results of the analyses of the fixed residue derived from the filter bed sands showed that of the 0.35 per cent fixed residue 0.1 per cent was silica, expressed as percentage of the weight of the sample

of sand originally taken, 0.15 was iron and aluminum oxides, most of which was aluminum oxide, and only 0.03 lime oxide and 0.01 magnesium oxide, leaving 0.1 per cent undetermined.

From this it is seen that what coating there is is largely organic and volatile matter and that of the mineral matter the largest proportion is aluminum oxide, coming probably from the floc of the aluminum hydrate which adheres to the sand grains. The calcium and magnesium oxides in this coating, as shown, are practically nil.

In considering the effects of carbonates on the sand it is well to remember that at numerous times during the first months of operation of the carbonating plant at Defiance carbonation was discontinued in order to make adjustments and repairs to the apparatus before it was finally shaken down to an operable condition.

In the autumn of 1922 it was discovered that when the meters were opened there was a dirty white deposit in the frost case and a green deposit in the gear case. One of these meters was forwarded to the author's laboratory in New York. These deposits were scraped out and an analysis was made of each, which is given below:

	SAMPLE NO. 259, FROST CASE DEPOSIT	SAMPLE NO. 260, GEAR CASE DEPOSIT
(1)	(2)	(3)
	per cent	*per cent*
Moisture at 105°C	4.1	3.9
Loss on ignition	25.24	33.82
Insoluble in acid	30.24*	21.54*
Soluble portion:		
Silica (SiO_2)	1.86	0.40
Combined oxides, mostly Fe_2O_3 and Al_2O_3	7.54	3.32
Calcium oxide (CaO)	0.56	1.14
Magnesium oxide (MgO)	0.44	0.12
Copper oxide (CuO)	None	34.85
Zinc oxide (ZnO)	27.32	None
Lead oxide (PbO)	None	0.44
Sulphate (SO_3)	2.16	0.98
Total	99.46	100.51
Carbonates	Present	Present

* This material, insoluble in acids, was subsequently decomposed with hydrofluoric acid and found to contain 27.5 per cent of silica in the case of No. 259 and 23.5 per cent of silica in the case of No. 260. Qualitative tests on the residues then showed the presence of iron and aluminum oxides and small amounts of calcium oxide, thus confirming the opinion that this material is clay or sand, or both.

As seen from these analyses, there is a considerable quantity of insoluble material in each deposit, which is probably in the nature of clay, sand, etc., coming from the deposits in the mains laid down prior to filtration. The silica reported was found in the soluble portion. There was also an appreciable amount of organic matter as indicated by the loss on ignition.

The combined oxides of iron and aluminum are quite low in each sample, as are also the quantities of lime and magnesia.

The frost case was of galvanized iron and the analysis of the deposit in this case, which was of a dirty white color, shows 27.32 per cent of zinc expressed as oxide. The gear case deposit was green in color and contained about 34.85 per cent of copper expressed as oxide.

Further investigations are being made along this line. The conclusions which appear reasonable regarding these incrustations at this time are:

1. That what incrustations there are may be largely due to the condition of the water during the early months of operation of the Defiance plant when the carbonation feature was often out of service for periods of several days at a time.
2. Recent experience has shown that there is still a large amount of mud in the service lines and this is often forced into the meters.
3. That a longer period of time is required for the collection of definite data.
4. There appears to be no noticeable increase in the deposits in the galvanized iron pipes and in the meters during the last six or eight months.

The design of the filter at Defiance was made by my associates, Mr. John N. Brooks, M.Am.Soc.C.E., and Mr. Allan T. Ricketts, M.Am.Soc.C.E., under my direction. Mr. Ricketts acted as Engineer in Charge during the construction. Mr. Frederick B. Barns, Assoc.M.Am.Inst.E.E., also one of my associates, was Resident Engineer. The analytical work herein presented was done by Mr. John E. Dowd, M.Am.Ch.Soc., Chemist and Bacteriologist in my office laboratory. Mr. H. T. Campion, Superindentent of the Defiance Water Works, coöperated with this office and furnished much material assistance both in the construction and breaking in of the plant.

Prof. D. D. Jackson of Columbia University gave the author some very helpful suggestions in connection with the design of the carbonating plant and application of CO_2 to the water.

In closing this paper it may be well to state that, whereas experiments have previously been made with the application of CO_2 to the effluent from water softening plants and desultory attempts have been made to use CO_2 as a final treatment in the lime softening plants as, for example, at Owensboro and Winnipeg, the Defiance plant is the first in which the CO_2 process has been developed in a practical form and has been used in actual and continuous operation. The author feels, from the results obtained at Defiance, that he is safe in saying that the CO_2 process is a decided step in advance where the lime softening process is used and that it will eliminate many troubles caused in a combined softening and filtration plant.

THE CLARION RIVER HYDRO-ELECTRIC DEVELOPMENT[1]

By Charles B. Hawley[2]

Within the last few months active construction work has been started on the first of a series of hydro-electric developments on the Clarion River. These power developments are of especial interest to the people of Pittsburgh in that the proposed dams will add to the flood protection of this district and will greatly facilitate the construction of any navigation improvements which in the future may be required on the Clarion River.

Usually the building of water powers involves more or less serious interference with previously established, or vested, interests in the right to the use of stream-flow, but the Clarion project is somewhat remarkable and fortunate in that the developments as laid out will conserve the existing vested interests.

In regard to these various interests in the right to the use of stream-flow, it may be said in general, that the chief public benefits resulting from the use of our streams are water supply, irrigation, navigation and water power development. These uses are not entirely harmonious; in fact, they are antagonistic in many respects and where a stream is put to two or more of these services, some compromise with respect to the conflicting interests is almost invariably necessary.

The use of stream flow for water supply for domestic and industrial purposes has always been considered, I believe, most important and necessary of all uses, but fortunately the amount of stream flow required for this purpose is usually insignificant in comparison with the total flow of streams which are large enough to be used for irrigation, navigation or water power. In those few cases where a large proportion of the stream flow is required for water supply, it sometimes is possible, as in the case of the Los Angeles aqueduct and water supply system, to use the water first in developing electric power before distributing it as water supply to communities.

[1] Presented before the Central States Section meeting, November 2, 1922.
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Here in the east irrigation has not as yet become a factor in determining prior rights to the use of water. However, as our country becomes older and more densely inhabited, the need for intensive farming will become greater and it is entirely probable that even our eastern streams will in a great many instances be forced to contribute water for irrigation purposes, especially in connection with those lands which are commonly termed "bottom lands" in the Central States. It is perhaps usual to think of irrigation as being required only in the dryer climates, but it is also extensively resorted to in countries which have very heavy rainfall, such as Japan, and will come into increasing use in this country as intensive farming makes it necessary.

On the other hand, the necessity for improving rivers for the purposes of navigation seems to be on the decline, except in the case of those streams which are of sufficient size and have sufficient depth of channel to make navigation easily possible. It is my opinion that the electrification of railways, which will surely continue as capital becomes available, will permit operating expenses of the railroads to be kept low enough to make railroad transportation preferable, as it is at present, for all products, where time of transit is of any consideration. Of course, there are even now many rivers where the existing use of the channel for navigation, practically blockades the stream so far as the development of water power is concerned. But as the value of electric power increases, and it is sure to do so in the future, the economical price of power development will tend toward higher levels, thus making it possible to absorb in construction charges the cost of locks which would have to be built in connection with power developments on navigable streams. In this connection we should not lose sight of the fact that these navigation facilities must be paid for by the power consumer, since development costs are reflected in power rates, with the result that the navigation interests will secure the benefits of slack water at the expense of electric power users.

The fourth important public benefit, already mentioned, as resulting from the use of our rivers, is water power, and it is not difficult to imagine the extensive series of water power developments which will be made along our streams, both large and small, within the next fifty years or so. Of course, water power development is practicable only on those streams which, having adequate stream flow, also have sufficient natural slope to permit an economical

accumulation of head by resorting to dams or conduits. Even in the case of some of these streams, the diversion and consumption of stream flow for water supply and irrigation will make hydro-electric development impossible. These instances will be rare, however, especially in view of the fact that water power projects may be laid out in so diversified a manner as to be kept within the particular limitations applying to any stream.

There are likewise other interests conflicting with water power development, but in the main all of these difficulties resolve themselves into a question of property damage, with one possible exception, and that is the occasional necessity, realized by a community, for constructing and operating dams for flood prevention purposes only. Even such dams, if properly laid out, may sometimes be operated for the joint purposes of water power and flood prevention, without undue compromise of interests.

The Clarion River, like all others of the larger streams, has its problems of interference in connection with the development of water power. These problems are chiefly in respect to the possible uses of this stream for navigation and for flood prevention as contemplated by the Pittsburgh Flood Commission. In laying out the various developments of the Clarion Hydro-Electric Project, the conflicting interests of navigation, flood prevention, and water power have been anticipated and the resulting problems effectively solved, with the result that all public interests in the stream flow of the Clarion River have been conserved. The possible future use of the stream for navigation and the present need of flood prevention in the Pittsburgh District have been provided for.

The Clarion River flows into the Allegheny River at a point between Parker's Landing and Foxburg, some 70 miles north of Pittsburgh. The drainage area of the Clarion at its mouth is nearly 1300 square miles. The hydro-electric project covers that portion of the river between its mouth and the city of Ridgway, a distance measured along the stream of approximately 90 miles, in which there is a natural fall of 475 feet.

Water power development of this stretch of river is best accomplished by the construction of three dams, the downstream dam, which we will call No. 1, to be located just a short distance above the mouth of the river; the intermediate dam, called No. 2, to be located a few miles below the Borough of Clarion; and the upstream, or Dam No. 3, located a little above the Borough of Clarion. Dam No. 1

will create a head of some 150 feet, Dam No. 2, a head of 80 feet, while Dam No. 3 will give a maximum head of 240 feet, and its reservoir will extend upstream to within a short distance of the City of Ridgway.

To develop completely the water power possibilities of any stream, equalization of stream flow throughout the year is essential. This can be realized only by the construction of dams for storage purposes. Now if a power plant is built to take water directly from such a dam, the drawdown of the reservoir incidental to the utilization of storage may so reduce the effective head on the water wheels as to reduce the power output below the normal demand on the system, although this demand could easily be met with the quantity of water available, were it not for this reduction of effective head on the turbines. When we consider that the power output of a water wheel decreases as the three halves power of the head it is apparent to what extent a reduction in head at a reservoir plant affects the total annual power output, as well as the daily power capacity. Of course, it is possible to offset this loss in power capacity of turbines by the installation of extra equipment for use at low heads only, but this involves an increased use of water at a time when the reservoir is low. If the plant is one of a series on the same river, best operating conditions will be secured by placing the requisite amount of reservoir capacity at the head waters of the river or at the dam furthest upstream, so that no loss of head due to drawdown need occur at any of the downstream plants. Another advantage of this arrangement is obvious when we consider that reservoir capacity at the plant located furthest downstream is effective for that particular plant only, whereas an equal amount of stored water at the upstream development would serve the entire series of power plants below. As mentioned before loss of head, due to drawdown of reservoir, is a very important consideration. For instance, a 50 foot drawdown in connection with No. 1 dam on the Clarion River would reduce the head on that plant by 33 per cent, and the peak load carrying capacity by 45 per cent, whereas an equal amount of drawdown at the upstream plant, No. 3, would reduce the aggregate head of the three plants, which is 470 feet, by approximately only 10 per cent, and the power by only 15 per cent. Such small reductions as these can easily be taken care of by proper proportioning of the various plant installations. Accordingly, the Clarion developments have been laid out with the intention of operating the two downstream plants with full reservoirs and practically constant

head at all times, depending entirely upon the upstream dam, No. 3, for stream flow regulation.

This program is also best suited to any future uses of the stream for navigation purposes. A fluctuation in the reservoir level would seriously interfere with the operation of locks and make navigation past a dam impossible during those times when the pond level was below the sill of the lock. Otherwise the lock chamber would have to have walls and gates of sufficient depth to extend below the minimum reservoir and lock levels by an amount equal to the depth of water required for navigation. For instance, if a lock is required around a power dam which is operated with a 50 feet drawdown, the height of the downstream lock gate would have to be 50 feet (the depth of drawdown) plus say 40 feet (the lift of the lock) plus 10 feet (the navigable depth of channel), a total of 100 feet. The construction of such gates, while not impossible, is, of course, expensive. Then, too, the fluctuation of reservoir level would interfere with the operation of dockage facilities along the reservoir, and the shipping interests would have to meet a condition even more exaggerated than that which prevails in a tidal harbor. In the case of tides normal depth of water recurs every twelve hours, but in the case of a storage reservoir a normal or maximum elevation of water could be counted upon only during the spring months after the reservoir had been filled. Accordingly, the Clarion project is best laid out with respect to navigation interests, since there will be but one fluctuating reservoir instead of several, and this reservoir will be so far upstream that there will undoubtedly never be a necessity for navigation above that point. In fact, it is difficult to imagine at this time that any portion of the Clarion River will ever be used for commercial navigation, although it is impossible to predict what changes in public necessity may occur in the future.

In a similar way, in the matter of flood prevention, the development of water power on the Clarion River will be a benefit to the Pittsburgh District. The power dams will absorb floods on the Clarion and will thus dampen the floods in the Allegheny River. Dam No. 3 will have a useful storage capacity of some thirty billion cubic feet (two hundred and twenty-five billion gallons) of water above low reservoir level. As this storage will be used to regulate the stream flow for all three of the major developments on the Clarion River, there will be comparatively few days in any series of years when the reservoir is completely full, and such days will occur

only for a brief period after the spring floods of particularly wet years. Accordingly, there would almost always be unfilled reservoir capacity available for absorbing unexpected floods on the Clarion River. Of course, with any flood prevention dam there is always danger that two floods will occur in succession, the first one filling the reservoir, making it necessary to discharge the entire peak of the second flood. But the Clarion dams will have a special factor of safety against such a contingency, in that the immense surface area of the three reservoirs will tend to absorb the peak of the second flood, even though the reservoirs are full.

As the general scheme for flood prevention in the Pittsburgh District involves the construction of dams on several of the streams which contribute their runoff to the Ohio River at Pittsburgh, it is safe to assume that a succession of two floods would not occur simultaneously or in synchronism on even two of these areas, so that in case a second flood should occur on any one of the improved streams, the other flood prevention units would have capacity to withhold temporarily the entire run-off from their respective catchment areas, thus keeping at a minimum the resultant hazard at Pittsburgh.

In the ordinary case of a dam built for flood prevention purposes only, it would be required that the reservoir be drained immediately after the occurrence of a flood or as soon thereafter as stream flow conditions below the dam permitted. Where a dam is used for the storage of water for power purposes, the water thus stored should be conserved for as long a period as possible. This essential difference in the operation of power dams and flood prevention reservoirs is of no moment in connection with the Clarion project, since, as explained before, the reservoir behind Dam No. 3 will very rarely, if ever, be at a maximum elevation for more than a few days at a time, and even when it is at a maximum elevation, the very large surface area of the three reservoirs, which have an aggregate length of nearly 90 miles, will tend to dampen effectively peak discharges during floods.

At Dayton where the Miami Conservancy Board has done most important and effective flood prevention work, the engineers have not depended entirely upon reservoir dams, since such dams are effective only with respect to relatively small catchment areas behind them. The Conservancy engineers have also resorted to channel improvements in the river at and near Dayton, including the straight-

ening, deepening and widening of the stream, and have also raised high embankment walls in order to keep floods within control.

The construction of water power dams on the Clarion River will do its part effectively to reduce floods at Pittsburgh, as will also the proposed extensive system of power dams on the Cheat River, but a suitable amount of channel improvement and embankment work, in addition to storage reservoirs on many tributary streams, may doubtless be required to afford Pittsburgh complete relief from its flood menace.

COLON-AEROGENES DIFFERENTIATION AT CINCINNATI

By Clarence Bahlman[1] and Henry Sohn[2]

Differential reactions for coli-like bacteria have received considerable attention within recent years. As a result of study by many workers, it has been demonstrated that bacteria formerly spoken of collectively as B. coli constitute a broad group of allied organisms which may be divided into at least two sub-groups, the B. coli, commonly found in the feces of man and many animals, and the B. aerogenes, rarely present in feces but predominating in the soil, in milk and on cereals. The reactions used in differentiating these bacteria, as given in the 1917 and 1920 edition of Standard Methods of Water Analysis, are shown in table 1. On account of the variability of the indole and saccharose reactions, these tests are of only subordinate value in the separation.

For several years the methyl red test has been made upon all confirmed lactose-fermenting cultures isolated at this plant, but during the year 1921 additional reactions have been employed, with the object of ascertaining whether coli-like cultures which would not conform to the reactions shown in table 1 could be isolated from our water, and to what extent such cultures would remain atypical after rejuvenation.

Unfortunately it was impossible to obtain adonite and this test had to be omitted. Chen and Rettger (1) and Winslow and Cohen (2), however, have found that adonite is attacked by aerogenes from both fecal and non-fecal sources, and hence the differential value of this alcohol seems to be discredited. Omitting adonite, then, our cultures may be divided into four sections, the well-recognized fecal B. coli; the predominantly non-fecal B. aerogenes; the B. cloacae type, of either fecal or non-fecal origin; and a fourth group in which the reactions are atypical.

Koser (3) has succeeded in differentiating the coli from the aerogenes types by the use of a medium containing no nitrogen except

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in the form of uric acid, B. aerogenes growing luxuriantly in this medium while B. coli failed to show the slightest evidence of growth. Chen and Rettger (1) also employed this medium with success, and we accordingly have included it in our studies.

Obviously the subdivision of coli-like bacteria into groups, subgroups, etc., is limited only by the number of tests employed. The fewer the number of reactions necessary to indicate the fecal or non-fecal origin of the culture, the less confusing and the more widely used will be the tests. In this work we have taken the methyl red test, the Voges-Proskauer reaction, growth or non-growth in uric acid medium and gelatin liquefaction as the only reactions necessary for the primary subdivision of the coli-like bacteria. If all of these bacteria will conform to the scheme given in Standard Methods, then cultures which are positive to methyl red should be Voges-Proskauer negative, and vice-versa. For this to be the case would be rather surprising. Since starting our work Perry and Monfort (4), in a somewhat similar study, have mentioned the difficulty of making all colon-group bacteria fit into the above system of classification, since the methyl red and Voges-Proskauer reactions of many of their cultures were not of opposite signs.

Procedure followed. Endo plates were streaked from the presumptive tube which, after forty-eight hours at 37°C., showed gas in any amount from the smallest volume of water tested. After twenty-four hours at 37°C. an agar slant was inoculated from one of the Endo colonies, whether typical or atypical, and incubated at 20°C. for forty-eight hours. This slant served as the parent culture from which the following 5 media were inoculated: lactose broth, Clark's broth, uric acid medium, peptone broth for indole test, and gelatin.

The uric acid medium was made according to Koser's formula; the other media were prepared according to Standard Methods, using Difco peptone except for the Clark's broth, in which proteose-peptone Difco was used.

The fermentation tubes were incubated forty-eight hours at 37°C., and the Clark's broth, peptone broth and uric acid medium for five days at 30°C. The gelatin cultures, after five days at 37°C., were immersed in ice-water and those which failed to congeal were recorded as liquefiers. Indole formation was determined by the Steensma-Nelson vanillin-test (5). One-half of the Clark's broth culture, after incubation, was poured into a clean test tube and used for the methyl red (M.R.) test. An equal volume of 10 per cent KOH was added to the remainder of this broth, and the mixture thoroughly shaken. These tubes were then placed in the 37°C. incubator and the Voges-Proskauer (V-P) reaction recorded after eight hours.

Number of cultures studied. During 1921 a total of 1825 samples of river, settled, coagulated (sulphate of iron and lime), filtered and chlorinated waters were examined for colon-group bacteria. Positive presumptives were obtained upon 1350 of these samples. Of this number, 1156 gave gas in the secondary lactose tube, after isolation from Endo medium. When no gas was found in this tube, another fermentation tube was inoculated from the parent slant, and in this way 67 cultures formed gas on the second test, although failing to do so on the first trial. This gives a total of 1223 out of 1350 cultures, or 90.6 per cent confirmed. These 1223 cultures form the basis of our study.

Of the 67 cultures which were confirmed only on the second test, 20 were B. coli by their subsequent reactions, 40 were aerogenes and 7 (all M. R. negative) failed to conform to any of the group reactions shown in table 1. It is interesting to note at this point the high percentage of M. R. negative organisms among the cultures which failed of confirmation except by a repeat test. This peculiarity is seen also in the tabulations of Perry and Monfort (4); 29 of their 39 cultures which failed to form gas after isolation from Endo plates were M. R. negative, and of these 22 were aerogenes on the basis of the M. R. and uric acid tests.

Grouping of the cultures. The M. R., V-P., uric acid and gelatin liquefaction tests were used as the basis for grouping our cultures. Although of variable intensity, the V.-P. and the uric acid reactions were always definitely positive or negative. In the great majority of cases there was no difficulty in recognizing the M. R. colors as either positive or negative, but where there was any doubt, due to borderland or neutral tints, the reaction was recorded as ±.

Gas-forming cultures which were neither coli, aerogenes or cloacae, as defined by table 1, were tentatively classed as atypical. Table 2 shows the distribution of the cultures according to our grouping, as well as a summary of the indole and gas reactions of the well-recognized groups. It will be noted that 15.3 per cent of the cultures could not be classified according to the scheme of Standard Methods.

It is recognized, of course, that the relative abundance of the various types in a water can be accurately determined only by the direct plating method. Isolation from the fermentation tube will give only an approximation of the truth, but it was impossible to burden our laboratory with so much additional work. The main object of this study was to effect a broad separation of coli-like

bacteria by a few cultural tests and then to study more intensively those cultures which proved atypical. With this procedure the presence of spore-bearing gas-formers, such as those described by Meyer (6), Ewing (7), Perry and Monfort (8), and Hinman and Levine (9), and the morphological peculiarities of the cultures, will pass unnoticed unless their cultural reactions were such as to throw them into the atypical class, since only atypical cultures were studied microscopically.

TABLE 1

Classification of coli-like cultures according to standard methods

GROUP	SOURCE	METHYL RED	VOGES-PROSKAUER	ADONITE	GELATIN	INDOLE	SACCHAROSE
B. coli ..	Fecal	+	–	–	–	Usually +	Usually –
B. aerogenes..	Fecal	–	+	+	–	Usually –	+
B. aerogenes..	Non-fecal	–	+	–	–	Usually –	+
B. cloacae.....	Fecal or non-fecal	–	+	+	+	Usually –	+

TABLE 2

Group distribution of 1223 coli-like cultures

GROUP	CULTURES		PERCENT OF CULTURES INDOLE +	PERCENT OF CULTURES SHOWING VARIOUS GAS VOLUMES		
	Number	Per cent		Under 10 per cent	10 to 40 per cent	Over 40 per cent
B. coli..........................	695	56.8	87.0	6.9	84.3	8.8
B. aerogenes....................	321	26.3	23.4	16.2	57.6	26.2
B. cloacae.......................	20	1.6	30.0	10.0	75.0	15.0
Atypical.........................	187	15.3				
Total..........................	1223	100.0				

Relation between source of water and percentage of positive presumptives confirmed. As stated above, 1223 or 90.6 per cent of the 1350 presumptive positives were confirmed. It has frequently been mentioned in published reports that as water passes through the various purification steps there is a gradual decrease in the number of confirmed tests, especially in the filtered and chlorinated waters.

It seems, however, that at this plant gas-formers other than true colon-group bacteria are not nearly as numerous as at many other localities. In water from any stage of our process there has never been less than 80 per cent of the presumptives confirmed, nor has there ever been any pronounced decrease in confirmations as the water was settled, coagulated or filtered. Confirmations in the chlorinated water, however, have always averaged a few per cent less than in the unsterilized waters.

Effect of season and of source of water upon abundance of fecal and non-fecal types. The non-fecal aerogenes type is said to be relatively more numerous at times of freshets when there is considerable washing of soil into the streams, but a study of our methyl red tests for four years has failed to reveal any correlation between rainfall or stage of the river and the relative proportion of the coli and aerogenes types in the water. Our system of isolating from the fermentation tube rather than by direct plating probably is the cause of this. The aerogenes subgroup, however, is found with greater frequency during the period from May to October when the temperature of the water stimulates many biological activities; apparently this organism is better able to survive competition which inhibits the more susceptible fecal strains.

No difference between the two types was apparent as regards ability to survive the treatment in the various processes of purification; approximately the same proportion of fecal and non-fecal types being found in all the waters.

Since starting the methyl red test in 1917, a peculiar decrease in positive reactions has been noted from year to year. The percentages of confirmed cultures from all sources which were methyl red positive were as follows: 1917, 83; 1918, 77.5; 1919, 65.9; 1920, (four months), 69.5; 1921, 62.4.

Indole formation and gas-volumes of coli and aerogenes cultures. Eighty per cent of our coli cultures and 23.4 per cent of the aerogenes strains were indole positive; this is in close agreement with the findings of other workers. Chen and Rettger (1) report that all of their 173 cultures of B. coli from feces, and 75 per cent of the cultures of this organism obtained from soil were indole positive, while only 31.5 per cent of the aerogenes strains formed indole.

The percentage of gas formed in the fermentation tube is influenced by many factors and at its best is of only minor significance. It will be noted from table 2 that our aerogenes and cloacae cultures

differ from the fecal strains in that the former very frequently show gas volumes either of less than 10 or of more than 40 per cent of gas. It seems that aerogenes is very apt to develop more than 40 per cent of gas in the fermentation tube; Chen and Rettger record that only 51 of 447 aerogenes cultures fell under 40 per cent in gas volume.

Study of the atypical cultures. By grouping according to the MR, V-P. and uric acid tests there are twelve possible varieties of gelatin non-liquefiers, as shown in table 3, and the same number of corresponding liquefiers. Purely for our convenience we have designated each of these possible types by a letter, except the well-known B. coli and B. aerogenes types. The gelatin liquefying

TABLE 3

Possible varieties based upon M.R., V-P and uric acid tests

	M.R.	V-P.	URIC ACID	OUR DESIGNATION
1	+	−	−	B. coli
2	+	+	−	Type A
3	+	+	+	Type B
4	+	−	+	Type UPC
5	−	−	−	Type C
6	−	+	−	Type D
7	−	+	+	B. aerogenes
8	−	−	+	Type E
9	±	−	−	Type F
10	±	+	−	Type G
11	±	+	+	Type H
12	±	−	+	Type I

culture corresponding to aerogenes is, of course, B. cloacae. There are, then, 24 possible reactions, three of these belonging to the well-known coli, aerogenes and cloacae sections, the others belonging to unnamed organisms classed by us as atypical. In our work we grew into the habit of designating the MR positive, V-P. negative uric acid positive organism, isolated by Chen and Rettger (1) from the soil, as "uric acid positive B. coli" or as type UPC, and we shall continue to use this appellation in this discussion.

The reactions given by a culture may be the more or less fixed characteristics of one organism in pure culture, or they may represent the combined reactions of two or more different species in mixed culture. Thus a culture containing both coli and aerogenes will

react positive to each of the above three tests. Re-plating and sub-culturing therefore is necessary to prove the purity of the atypical cultures.

Procedures used on atypical cultures. A new 48 hour 20°C. agar slant was prepared and the fermentation of lactose, the M.R.,V.-P., uric acid and gelatin tests were repeated from this. If by these repeat tests the culture now fell into any of the three well-known groups (coli, aerogenes and cloacae) no further studies were made. (In studying the atypical cultures the action upon gelatin was noted after five days and also after fifteen days at 37°C.).

If the culture still remained atypical it was invigorated by four successive transplants in nutrient broth, each of these being incubated for 24 hours at 20°C., as described in the 1912 edition of Standard Methods. Gelatin plates were prepared from suitable dilutions of the last broth tube, incubated at 20°C., for 48 hours, and an agar slant inoculated from each of four of the colonies upon the plate. If the culture being studied was a gelatin liquefier, agar plates were used, so that additional sub-cultures were always available at any time during the subsequent observations.

The tests were then repeated upon the four sub-cultures. If all of these gave the same reaction as the original, the latter was assumed to have been a pure culture of an organism the cultural characteristics of which are more or less permanent, since ordinary rejuvenation caused no changes in reaction. One of the sub-cultures was then kept for additional study.

If the sub-cultures reacted differently, although one or more of them was identical with the original or was a lactose-fermenter not fitting into the Standard Methods classification, the atypical sub-cultures alone was retained for further observation. The parent culture in such a case was considered to have contained an unclassified coli-like organism in mixed culture with one or more other species.

If the original reactions were lost in all four of the sub-cultures, additional colonies were fished from the plates which in the meantime had been stored in the refrigerator. If it was impossible to duplicate the original reactions by from 7 to 10 sub-cultures from the plate, and all of these sub-cultures acted alike, then it was assumed that the original organism either was lost in the manipulations or else had undergone a change in its cultural reactions. In many instances the results upon the sub-cultures proved that there were two or more different organisms in the parent culture and that the reactions of these in the mixed culture would account for the original results.

Finally, fresh slants were prepared from all of the cultures which still remained atypical after the above procedures, and from these various carbohydrate broths (0.5 per cent) were inoculated. These were incubated for four days at 37°C. and gas formations noted after this time. A twenty-four-hour broth culture was used for motility observations; the reaction to Gram's stain was determined from a forty-eight-hour agar slant.

Grouping the atypical cultures. Table 4 shows the distribution of the 187 tentatively atypical cultures among the lettered types

mentioned above, the number of these cultures remaining after repeating the tests, and the number which still retained their original reactions after rejuvenation and replating. The percentages of these final, persistently atypical cultures which gave gas formation in the various carbohydrate broths, and the percentages showing indole formation, are also given in this table. Similar percentages for cultures of typical B. coli, B. aerogenes and B. cloacae, selected at random toward the end of the investigation and proven to be pure cultures by re-plating, have been placed at the bottom of the table for the purposes of comparison.

A detailed account of the behavior of the organisms of each type, when studied as above, will serve to throw some light upon the permanency of the reactions of cultures which cannot be included in the well-recognized groups.

ATYPICAL GELATIN NON-LIQUEFYING CULTURES

Type A (MR+, VP+, uric acid−): Of the 12 possible varieties of gelatin non-liquefiers, type A was the only one which we failed to encounter in this study.

Type B (MR+, VP+uric acid+): Three of these cultures were isolated in the routine work; two of these became MR negative on repetition. All of six sub-cultures from the remaining MR positive culture, moreover, gave a color with this indicator which would undoubtedly be classed as negative although four of them had a faintly orange cast. Variations in hydrogen ion concentration may be expected of all bacteria, and Chen and Rettger have shown that the composition of the media, the length of incubation and even the brand of peptone may cause discrepancies in the MR test. Our type B cultures, therefore, probably are aerogenes strains which failed to develop normal hydrogen ion concentrations under the conditions of the test.

Type UPC (MR+, V-P−, uric acid+): Koser (3, 10) has observed that B. aerogenes was able to develop in a medium in which uric acid furnished the only source of nitrogen while B. coli was unable to utilize the nitrogen of the purin ring and failed to grow. Chen and Rettger found, similarly, that 173 strains of B. coli isolated from feces failed to develop in the uric acid medium. They report, however, that 10 out of 20 coli strains isolated from soils grew just as luxuriantly as typical aerogenes in this medium. They point out that this lack of correlation suggests the possibility that

these strains may represent a type intermediate between coli and aerogenes.

Perry and Monfort (4) isolated 63 MR positive, uric acid positive varieties out of 392 cultures isolated from natural waters; we found a much smaller percentage, 46 out of 1223 cultures. Three of these were V-P positive and belong in our type B, the remaining 43 cultures we will speak of as "uric acid positive B. coli" or type UPC. Let us note at this point that several of these cultures were recorded as only "slightly positive" to uric acid. With all other types growth in this medium was either very pronounced or entirely lacking.

Fifteen of the 43 cultures failed to repeat. Four of these changed both their MR and VP results and became typical aerogenes; four became MR negative and thus assumed the reactions of type E, two changed from uric acid positive to uric acid negative and thus appeared to be typical B. coli. Five cultures at first appeared to repeat their original reactions although the growth in uric acid medium was not nearly as pronounced. A second repeat upon these five cultures, from the parent slant which by this time was seven days old, surprised us by failing to show any development whatsoever in the Koser medium, the cultures now appeared as typical B. coli.

The growth in uric acid of ten of the 28 cultures still remaining in type UPC, moreover, was noticeably less marked than in the original tests. It seems that for some reason these cultures were gradually losing their ability to utilize the uric acid nitrogen.

The results upon rejuvinating and replating these 28 cultures were as follows:

2 cultures showed only aerogenes in pure culture
10 cultures showed only B. coli in pure culture
6 cultures showed only type E in pure culture
1 was a mixed culture of type E and B. coli
3 (all chromogenic) were mixed cultures of B. coli and a MR negative, VP negative, uric acid positive chromogenic non-gas-former
2 cultures were mixed cultures of B. coli and a MR positive, VP negative, uric acid positive non-gas-former
4 cultures retained their original reactions

The reactions of the constituents of the six mixed cultures will account for the original results and probably there were no type UPC organisms in the first cultures. Only four of the 22 apparently pure cultures remained as type UPC, and ten of the 22 now failed to grow in uric acid medium.

Variations in the MR and VP reactions have been alluded to in the literature and have occurred frequently in our study, but, with one exception, (see type E liquefiers) all instances of a change in uric acid reaction have been confined to cultures originally MR positive, VP negative, uric acid positive. As soon as this peculiar behavior was impressed upon us, heroic efforts, involving the examination of from 10 to 15 colonies from each plate, were made to recover uric acid positive organisms in the cultures which gave this reaction when freshly isolated from the water, but which seemed to lose the characteristic after one or more platings on laboratory media.

Our failure to accomplish this seemingly indicates that the uric acid test, so permanent with all of the other varieties, is variable in the type designated by us as UPC; that the latter is an unstable variety prone to alter all three of its reactions. By a change in both the MR and VP tests it assumes the characteristics of aerogenes, by changing the MR result only it falls into type E. More frequently, however, it loses its positivity toward uric acid and then seems to be typical B. coli which temporarily had assumed the power of utilizing the uric acid nitrogen. The tendency to revert to aerogenes and the closely allied type E in some instances, and to typical B. coli in others, would seem to strengthen the suggestion put forth by Chen and Rettger, that coli strains which are positive to uric acid belong to a type intermediate between coli and aerogenes.

Type C (MR−, VP−, uric acid−): Three of these cultures, upon repeating the tests, became acid to methyl red and were then classed as fecal B. coli. There was considerable orange, however, in the color with the indicator. One of the cultures showed a faint but undoubtedly positive VP test on the second test, thus becoming type D. The 12 cultures still remaining as type C were then invigorated and replated with the following results:

1 culture became VP positive, thus changing to type D

1 culture remained negative to the three tests but no longer fermented lactose and showed sluggish liquefaction of gelatin after fifteen days at 37°C.

2 cultures showed only typical coli, with the normal distinctly acid reaction to methyl red

5 cultures contained both type C and fecal B. coli, but the acidity of the coli subcultures was not as pronounced as usual

3 cultures remained unchanged, with distinctly negative MR reactions

This type seems to be closely allied to B. coli, the MR reactions showing a tendency to become more acid and thus at least to approach the behavior of typical coli. The original negative MR reaction was still retained, however, by one-half of the cultures after the invigorating process.

Type D (MR−, VP+, uric acid−): Two of these 14 cultures, positive by presumptive test, failed to ferment lactose on the first test from the Endo plate, although a second lactose tube was positive. These two cultures and two others, on repeating all of the tests, still retained their MR, VP and uric acid reactions but again refused to give gas in lactose tubes, even when incubated anaerobically. Two of the four cultures showed spores under the microscope.

The ten remaining cultures repeated their reactions in all respects and were then invigorated and replated with the following results:

1 culture no longer fermented lactose or any of the ten other sugar and allied broths

2 cultures no longer fermented lactose even in 4 days, although they formed gas readily from dextrose, saccharose, mannite, raffinose, dextrin and salicin. Spores were not present

2 cultures contained both a type D lactose fermenter and a MR negative, VP positive, uric acid negative organism, not fermenting lactose but giving gas from dextrose, saccharose, mannite, raffinose and salicin

5 cultures apparently were pure type D strains, all formed from 20 to 40 per cent of gas in lactose broth and all of them, as well as the 2 type D cultures which had been mixed with a lactose −, dextrose+ organism, were indole negative. All seven of these cultures were gelatin negative after five days but liquefied this medium in fifteen days

The type D reactions are therefore quite permanent, none of the cultures having altered them in the course of our study, but the frequency with which the power of fermenting lactose is lost is peculiar. Type D cultures, considered here as non-liquefiers on the basis of the five-day test, were really slow liquefiers.

Type E (MR−, VP−, uric acid+): Almost one-half of our atypical cultures belong to this type. On repeating the tests, 21 of the 69 cultures developed a positive, although usually rather faint, VP reaction, while 48 repeated the original reactions. The fate of the latter cultures on rejuvenation and replating is given below:

10 became VP positive, thus appearing as aerogenes
3 remained MR negative, VP negative, uric acid positive but would no longer ferment either lactose or dextrose. These cultures were flourescent in all media
3 were mixed cultures of a MR negative, VP negative, uric acid negative lactose fermenter (type C) and a MR negative, VP negative, uric acid positive chomogenic non-gas former
2 were mixed cultures of B. coli and a MR negative, VP negative, uric acid positive chromogenic non-gas former; a rather unexpected instance where a MR negative organism obscured the MR positive reaction of the coli
4 were mixed cultures of type E and a MR negative, VP negative, uric acid negative chromogenic non-gas former, liquefying gelatin after fifteen days but not after five days
26 still persisted as a type E, apparently in the pure culture. Ten of these were rejuvenated and replated a second time and the tests repeated. All of the 10 still gave the type E reactions

It was noted in the routine work that many of the type E cultures were decidedly fluorescent in all the media, but in all cases the chromogenesis was subsequently shown to be caused by a contaminating non-gas former.

In being permanently MR negative and uric acid positive and because of their so frequently becoming VP positive it would seem that type E is to be regarded as a variant of aerogenes.

Type F, G, H, I: On repeating the tests upon the 16 cultures which yielded neutral tints with methyl red the reaction in 11 instances became definitely positive or negative, while 5 cultures (all type I) still gave indeterminate colorations. On replating, however, all of the 16 cultures gave clear-cut methyl red reactions and in no instances could mixed cultures be demonstrated.

The type F cultures were the only ones which became MR positive the cultures then appearing to be typical B. coli.

The type G culture, by becoming MR positive then had the characteristics type D and, like the latter cultures, gelatin liquefaction, negative in five days, was positive after fifteen days incubation.

The 3 type H cultures became MR negative and lost their VP reaction. The subcultures, moreover, showed only a slight growth in the uric acid medium; our type H cultures had therefore changed to type E. Additional subcultures were examined but in no instance were we able to recover VP positive bacteria.

The 5 type I cultures also fell into type E after replating.

ATYPICAL GELATIN-LIQUEFYING LACTOSE FERMENTERS

Type C gelatin liquefiers: One of these cultures gave deep red colorations in all media. Replating showed the culture to contain a type C non-liquefying gas former and chromogenic type C bacillus which liquefied gelatin and would not frement lactose.

The other two cultures, however, were shown to be pure by the replating procedures, all subcultures yielding type C reactions, fermenting lactose and liquefying gelatin.

Type D liquefiers: All six of these cultures repeated their reaction. On replating the following results were obtained, no mixed cultures being found: 2 cultures no longer reacted to the VP test nor liquefied gelatin even after fifteen days, then appearing as type C cultures. One culture retained its MR, VP and uric acid reactions but no longer fermented any of the sugars, etc., shown in table 4. 2 cultures, while retaining their type D reactions, now refused to ferment lactose although forming gas from dextrose, saccharose, mannite and dextrin. Spores were found in one of these cultures. 1 culture remained a type D gelatin liquefier lactose frementer after replating.

There is really no difference between our type D and the type D gelatin liquefiers, since the former was shown to be a slow liquefier. It is peculiar that so many of these cultures (10 out of 20) should have lost their lactose-forming properties.

Type E gelatin liquefiers: Gas formation was lost on repeating the tests upon 4 of these cultures; 1 culture developed a faint VP reaction and then appeared to be cloacae, while 4 cultures retained their original characteristics.

Subcultures from one of the latter 4 cultures no longer liquefied gelatin, uric acid positivity disappeared and the MR reaction changed to positive, in other words, the culture now appeared as typical B. coli. Two of the 4 cultures on rejuvenation gave the VP test, thus acting like cloacae, while the remaining culture was the only one from which a type E liquefying gas former was recovered, although some of its subcultures were cloacae with fairly intense VP reactions.

The type E gelatin liquefying reactions, therefore, seem to be largely due to a variant of B. cloacae which finds difficulty in yielding the VP test.

Type B. coli liquefier (MR+, VP−, uric acid−, gelatin+): Seven of these 8 cultures were chromogenic in all media. On replating,

TABLE 4

Distribution and carbohydrate reactions of atypical cultures

Type	Reaction: M. R.	V-P.	Uric acid	Gelatin (5 days)	Number of original cultures	Number cultures remaining after: Repeat test	Rejuvenated	Per cent of cultures remaining after rejuvenation which formed gas from: Dextrose	Lactose	Dulcite	Saccharose	Mannite	Raffinose	Inulin	Starch	Glycerine	Dextrine	Salicin	Per cent indole +
A	+	+	−	−	0	0	0												
B	+	+	+	−	3	1	0												
UPC	+	−	+	−	43	28	4	100	100	0	100	100	100	0	0	0	25	100	75
C	−	−	−	−	16	12	8	100	100	17	100	100	100	0	0	100	25	0	100
D	−	+	−	−*	14	10	7	100	100	0	100	100	100	0	0	0	100	100	0
E	−	−	+	−	69	48	30	100	100	23	97	100	100	23	75	92	98	98	70
F	±	−	−	−	7	0	0												
G	±	+	−	−*	1	0	0												
H	±	+	+	−	3	0	0												
I	±	−	+	−	5	5	0												
C, liquefr.	−	−	−	+	3	3	2	100	100	50	0	100	0	0	0	0	100	0	100
D, liquefr.	−	+	−	+	6	6	1	100	100	0	100	100	100	0	0	0	100	100	0
E, liquefr.	−	−	+	+	9	4	1	100	100	0	100	100	100	0	0	0	0	100	0
B. coli liq.	+	−	−	+	8	8	0												
Total					187	125	53												
B. coli	+	−	−	−			30	100	100	27	47	100	53	0	0	87	0	33	
B. aerogenes	−	+	+	−			30	100	100	50	100	100	100	0	20	100	10	100	
B. cloacae	−	+	+	+			30	100	100	47	100	100	100	0	13	27	60	100	

* Gelatin + in 15 days.

5 of the chromogenic cultures were shown to be mixed cultures containing typical B. coli and a chromogenic gelatin positive lactose non-fermenter acting negative to the MR, VP and uric acid tests. All subcultures from the remaining two chromogenic forms failed to ferment lactose, the original gas-producer probably having been lost or overgrown in the manipulations. (Throughout the entire study, whenever a chromogenic lactose-fermenting culture was obtained, the chromogenesis in all cases was shown to be due to the presence of bacteria which formed no gas from lactose.)

The non-chromogenic culture became MR negative on replating, thus appearing to be a type C liquefier in pure culture.

Carbohydrate reactions. In order to compare the 53 atypical cultures with typical strains in respect to gas formation from various carbohydrates, 30 pure cultures each of coli, aerogenes and cloacae were obtained by rejuvenation and replating. Several aerogenes cultures, gelatin negative in 5 days, proved to be liquefiers after the fifteen day inccubation and then were classed as cloacae. Cloacae cultures therefore were really more numerous, and aergoenes less numerous, than reported earlier in this paper on the basis of a 5 day gelatin test.

To express the results as "percentages of cultures which formed gas," as we have done in table 4, gives us a crude means of comparing the data, but too much reliance should not be placed upon the results because the number of cultures of each type in most instances is too small to permit of definite conclusions as to the gas reactions.

The 8 type D cultures were the only strains which could not be subdivided by the carbohydrate reactions, but the members of all of the other types could be further differentiated by their variable reactions with dulcite, saccharose, raffinose, inulin, starch, glycerin, dextrin and salicin. Table 4 shows that all of the 53 atypical and 90 typical cultures formed gas from dextrose, lactose and mannite, while saccharose, raffinose and salicin were also fermented by the majority of strains.

It is known that practically all gelatin non-liquefiers of the colon group will ferment glycerin, while the gelatin positive cultures are mostly glycerin negative. With the exception of type UPC, all of our atypical cultures show a good correlation of these tests, but 13 per cent of the non-liquefying coli strains were also glycerin negative and 27 per cent of the cloacae strains were glycerin positive.

The type E cultures are unique in that they were the only cultures fermenting inulin and because as high as 75 per cent of them fermented starch. The close relationship of these organisms to B. aerogenes, indicated by their behavior following rejuvenation, is again shown by their ability to ferment starch.

MICROSCOPIC CHARACTERISTICS

Microscopic examination. A microscopic examination was made upon the 53 atypical and 90 typical cultures used in studying the fermentation reactions. Except in a few instances any difference between the types, as revealed by this examination, were not of sufficient magnitude to be worthy of much note.

All of the cultures were Gram-negative and free from spores. In morphology and in motility as revealed in hanging drops there often was a slight difference even among the cultures belonging to the same group. Most of the coli cultures were short rods, rather sluggishly motile, although some were almost coccoid and a few were non-motile. The cloacae cultures generally were more actively motile than the coli. Twenty-two of the aerogenes cultures were either non-motile or else endowed with a rather doubtful sluggish movement, the others were sluggishly motile. A faint capsule was demonstrated on one of these cultures which showed ropiness on agar.

Among the atypicals there was the usual slight variations in size and shape, although all were distinctly bacilli. The four UPC cultures and the 8 type C cultures all were exceedingly motile, giving the appearance of vigorous typhoid bacilli in hanging drop. The other atypical groups showed different degrees of motility among the members of each group, but none of them approached the activity of the UPC and type C cultures.

SUMMARY

1. Confirmed colon group cultures numbering 1223 were grouped according to their methyl red, Voges-Proskauer, uric acid and gelatin reactions. Of these cultures 56.8 per cent were B. coli, 26.3 per cent were B. aerogenes, 1.6 per cent were B. cloacae and 15.3 per cent (187 cultures) were classed as atypical.

2. Correlation of rainfall and high river stages with the relative abundance of coli and aerogenes was not apparent, nor did the

degree to which the water was purified have any bearing upon the incidence of these two sub-groups. For several years, however, the aerogenes strains were found with greater frequency from May to October, and occasionally were the preponderant types during warm weather.

3. On the basis of the methyl red, Voges-Proskauer, uric acid and gelatin reactions there are 24 possible types of lactose fermenters; three of these are the well-known coli; aerogenes and cloacae types and the remaining 21 are unclassified.

4. Fourteen of these 21 possibilities were represented in the 187 atypical cultures encountered in our routine work.

5. On repeating the tests upon these 187 cultures, 45 reverted to typical coli, aerogenes or cloacae; 9 changed one or two of their reactions and thereby entered into one of the other atypical groups; 8 no longer fermented lactose, and 125, representing 10 of the 21 possible types, retained their original reactions.

6. The invigoration and replating of these 125 cultures showed that the reactions of 17 were due to mixed cultures; 12 no longer fermented lactose, 28 assumed typical reactions, 15 changed over into another atypical class, and 53, (representing 7 of the 21 types and 4.3 per cent of the total number of cultures) retained their original reactions, without any indication of the presence of contaminating forms.

7. During this study there were 33 instances of a change in methyl red reactions, 38 of a change in Voges-Proskauer, 9 where both of these tests changed, and 19 instances where the uric acid reaction altered. With one exception, all of the changes in the latter reaction were confined to one of the atypical varieties, which appeared to be intermediate between coli and aerogenes and to lose its positivity toward uric acid after growing for some time on laboratory media.

8. The fate of the atypical cultures on invigoration has been outlined, from which it appears that, although many of the non-correlated reactions were due to mixed cultures and many of the apparently pure strains showed a close relationship to typical forms, still a large proportion of the atypicals (28.3 per cent) consistently retained their original characters.

9. Most of the atypical groups could be further subdivided by their carbohydrate fermentations. The MR negative, VP negative, uric acid positive non-liquefying strains differed markedly from the other typical and atypical groups in the frequency with which they fermented inulin and starch.

10. All of the persistently atypical cultures were Gram negative, non-spore-forming rods. All of the type UPC and type C cultures showed very active motility; the other types were either non-motile or only sluggishly motile, and slight differences were noted between members of the same group.

CONCLUSIONS

Purification of cultures which do not fit into the well-defined subdivisions of the colon group of bacteria will materially reduce the number of non-correlating reactions, but many of the atypical cultures are quite permanent. In this work 53 cultures (4.3 per cent of the number studied), representing seven different non-conforming types, survived the invigoration and replating processes and remained atypical in apparently pure culture.

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(8) Perry and Monfort Bulletin 16, Illinois State Water Survey, 223–229.

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THE CONSTRUCTION OF LOCH RAVEN DAM[1]

By Wm. A. Megraw[2]

Baltimore is engaged in making what is known as the Gunpowder improvement to its water supply. The plans include a dam at Loch Raven on the Gunpowder river to impound 23 billion gallons of water, and a balancing reservoir to limit the pressure on a 7 mile tunnel conducting water to the city, together with the necessary relocation of roads and bridges, the purchase and removal of the villages of Warren and Phoenix, the relocation of 1.5 miles of Pennsylvania Railroad tracks near Phoenix, the purchase of about 4000 acres of land from 54 different owners and clearing the ground to be flooded of buildings, trees and vegetable matter.

The principal feature is the Loch Raven Dam, which is nearing completion. Plans were first prepared in 1913 and the work completed during year to elevation 188 feet above mean tide, the base being made broad enough to support the additional section necessary for raising the dam later to elevation 270. The plans, under which the present contract is proceeding, provide to raise the dam from elevation 188 to elevation 240. The dam is a solid concrete structure, 640 feet long over all. The spillway is 288 feet long and rises about 103 feet above bed rock. (See figures 1 and 2.)

In designing the cross section, upward pressure was assumed on all horizontal joints, equal to the full hydrostatic pressure at the upstream face, decreasing to zero at the downstream face. Porous drains in the horizontal joints, which will be described later, are provided to relieve upward pressure. Two 48 inch pipes passing through the old foundations control the ordinary flow of the river and enabled all concrete to be deposited on dry surfaces. One inch bent steel rods 5 feet apart horizontally and vertically, imbedded three inches back of the down stream face, can be straightened to assist in binding the new concrete to the old, in case the dam is ever raised to a higher elevation.

[1] Presented before the Philadelphia Convention, May 16, 1922.

[2] Formerly Water Engineer, Baltimore, Md.

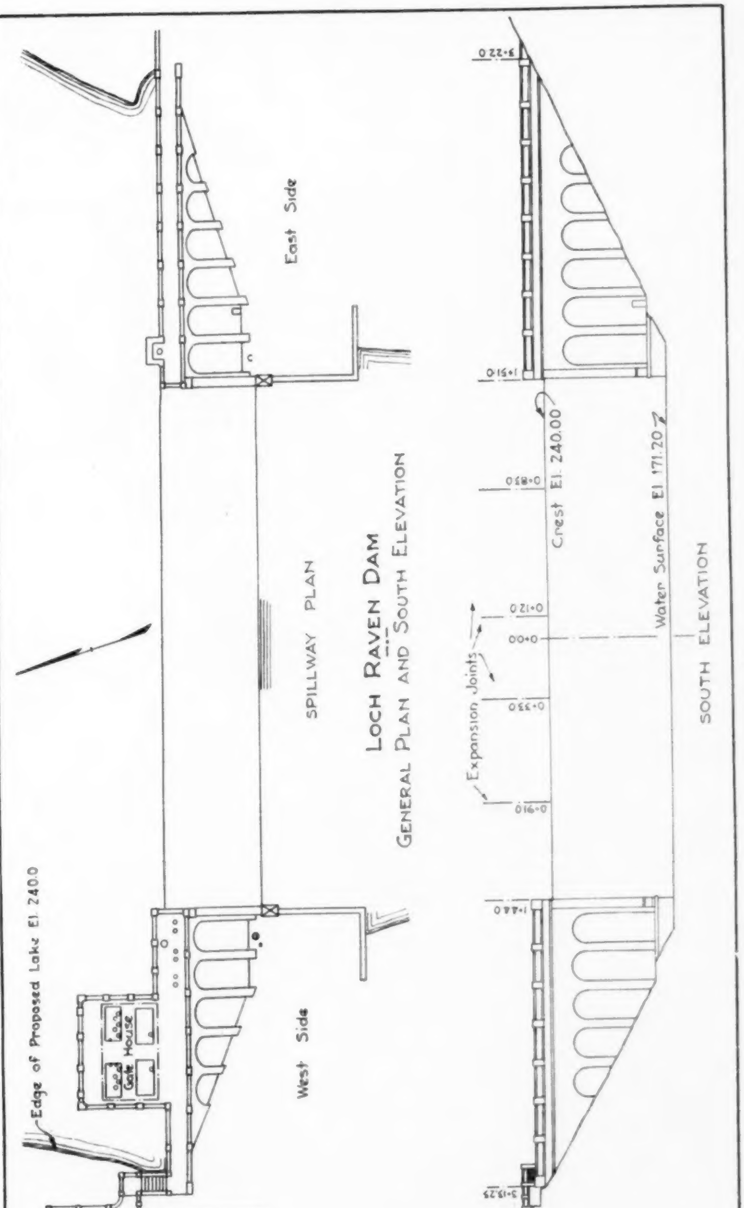

LOCH RAVEN DAM
GENERAL PLAN AND SOUTH ELEVATION
SPILLWAY PLAN
East Side
West Side
Gate House
Edge of Proposed Lake El. 240.0
Road
Crest El. 240.00
Water Surface El. 171.20
Expansion Joints
SOUTH ELEVATION

FIG. 1

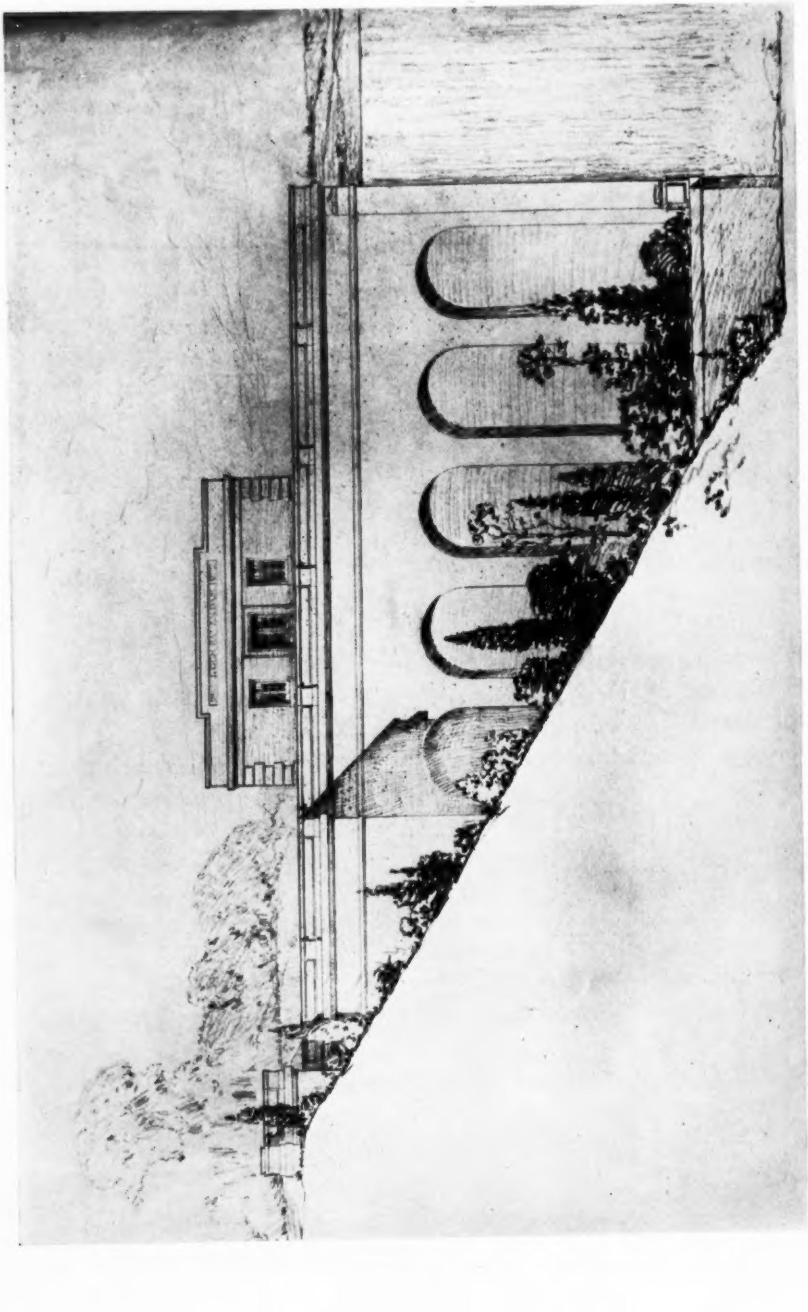


FIG. 2

The gate chamber is divided into two separate compartments and each is designed to supply the city separately. Fifteen sluice gates, $3\frac{1}{2}$ by 6 feet, arranged at different heights, control the entrance of water.

The dam is located between steep hillsides and the available working space is small. (See figure 3.) Stone was furnished from a city quarry located on the west side of the river 3000 feet down stream from the dam. An improved highway extends from a point on the hillside opposite and above the dam down to and past the quarry to Loch Raven Station on the Maryland and Pennsylvania Railroad about 2200 feet farther down. The railroad at Loch Raven Station is approximately at right angles to the river and follows along a steep hillside about 50 feet above the highway, which turns and parallels the railroad in both directions. A siding about 1600 feet west of the railwood station provides a means of handling materials from the railroad by gravity to the highway below. An old city-owned siding 1.6 miles long is located on the east side of the river and extends from the dam southerly to a point where the railroad, 1.2 miles east of Loch Raven Station, meets it at grade. This arrangement of highways, railroads and sidings, offered several means of handling the work of construction.

The contract was awarded to the Whiting-Turner Construction Company of Baltimore on April 6, 1921, and about July 1, the first concrete was deposited. The bulk of the work was completed by January 1, 1922.

The specifications permitted the use of cyclopean concrete, but the contractor installed a chute system for distribution, which precluded the depositing of large stones, except in the east shore section, where a derrick, used for excavating the east abutment, swung a portion of the larger stones into the dam. The chute system was designed by the Lakewood Engineering Company. (See figure 4.)

On the west side of the river, the topographical conditions are ideal for a gravity plant. The contractor, availing himself of this advantage, located his crusher, storage bins and mixing and distributing plant up and down the west hillside just south of the site for the dam, although the city siding on the opposite side of the river connected the dam directly with the main line of a railroad.

Cement was the only material hauled by railroad. On the hillside below the siding at Loch Raven Station, a cement house was built with the capacity of 5000 barrels. The cement was here received in

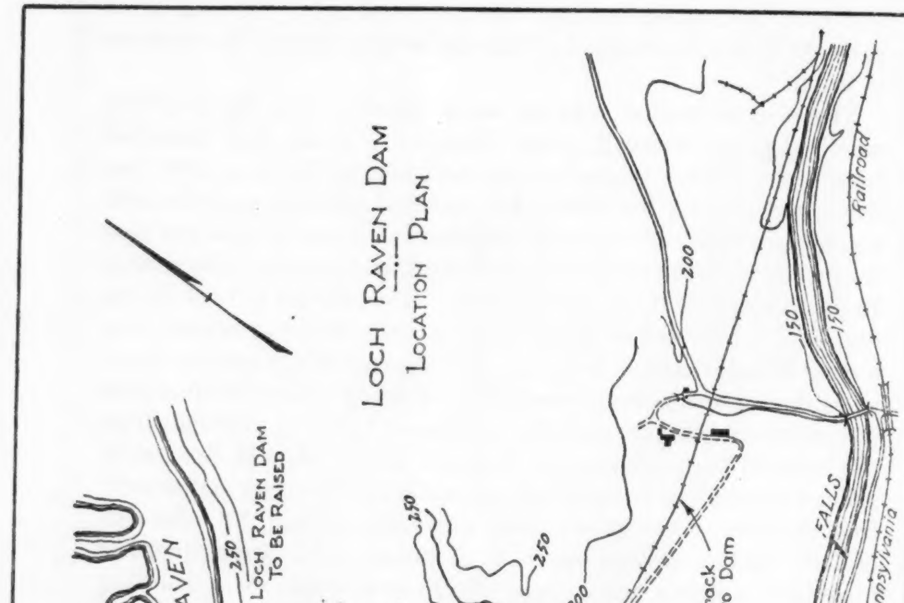

Loch Raven Dam
Location Plan
Loch Raven Dam
To Be Raised
Raven
Loch
Reservoir
Old Stone Dam
Existing Spur Track
Summerfield Sta. to Dam
Gunpowder
Falls
Pennsylvania
Railroad
Maryland
Loch Raven Sta
12'-0" Tunnel
10'-0" Conduit
Gate Keeper's House
300
250
200
150

FIG. 3

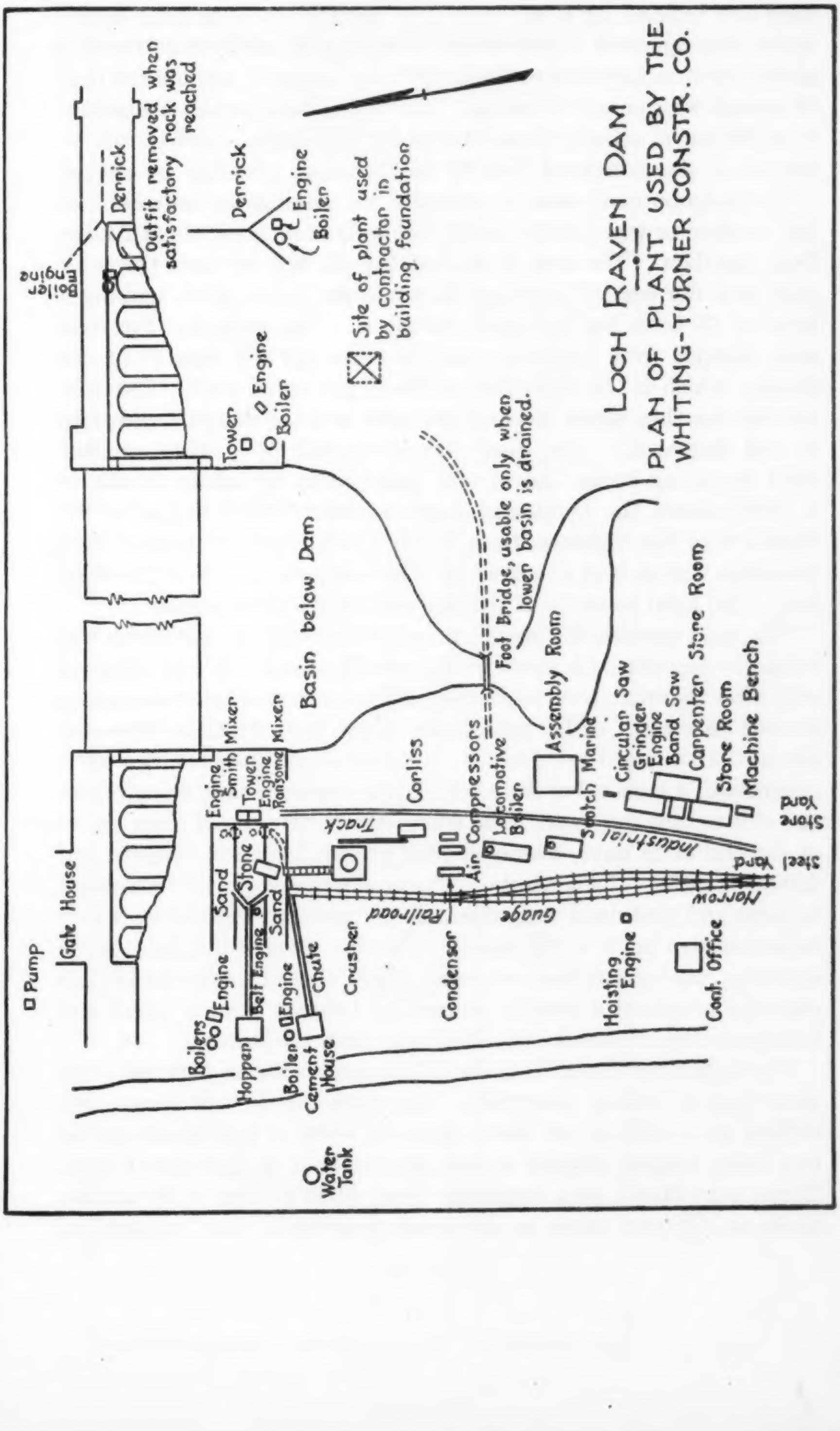

LOCH RAVEN DAM
PLAN OF PLANT USED BY THE
WHITING-TURNER CONSTR. CO.
Site of plant used by contractor in building foundation
Outfit removed when satisfactory rock was reached
Derrick
Boiler
Engine
Tower
Gate House
Pump
Boilers
Hopper
Belt Engine
Sand
Stone
Smith
Ransome
Mixer
Cement House
Chute
Crusher
Water Tank
Basin below Dam
Foot Bridge, usable only when lower basin is drained.
Corliss
Track
Air Compressors
Condensor
Railroad
Narrow Guage
Locomotive Boiler
Scotch Marine
Industrial
Assembly Room
Circular Saw
Grinder
Band Saw
Carpenter Stone Room
Store Room
Machine Bench
Stone Yard
Steel Yard
Hoisting Engine
Cont. Office

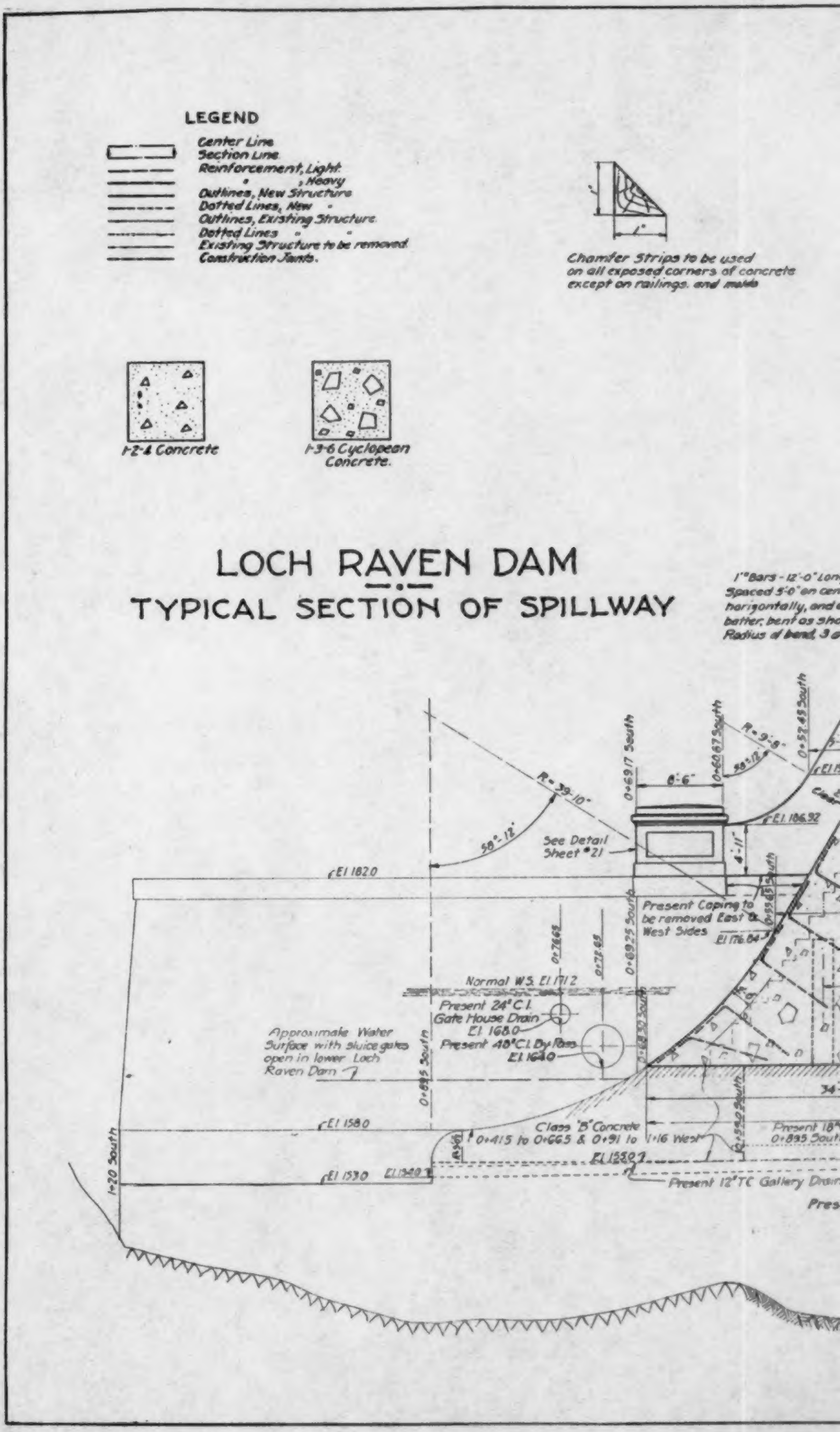
FIG. 4

bags and handled by a belt conveyor operated by a gasoline engine which also operated a bag shaker consisting of a wire cage rotating about seven minutes for each charge. By means of a chute the bags of cement were passed to trucks. The trucks transported the cement to a 200 barrel capacity shed located on the hillside above the plant, whence it was conveyed directly to the mixer platform by chutes.

The neighborhood sand is generally not suitable for concrete, but the contractor was able to locate an excellent sand pit about 2 miles from the dam. The cost of sand at the pit was 24 cents per cubic yard and the cost of trucking 44 cents per cubic yard, making a total of 68 cents for the sand delivered. The quotation for river sand shipped from Baltimore was 70 cents per ton plus $1.14 for freight, which is the equivalent of $1.45 per cubic yard. The contractor was thus saved 75 cents per yard and the delays consequent to rail shipment. The sand was excavated by a three-quarter yard revolving steam shovel and transported by motor trucks to a point above the plant and dumped directly into a hopper at the elevation of the highway, from which a belt conveyor carried it to two large storage bins, one of which is located on each side of the stone bin. The total capacity of the two bins is 500 cubic yards.

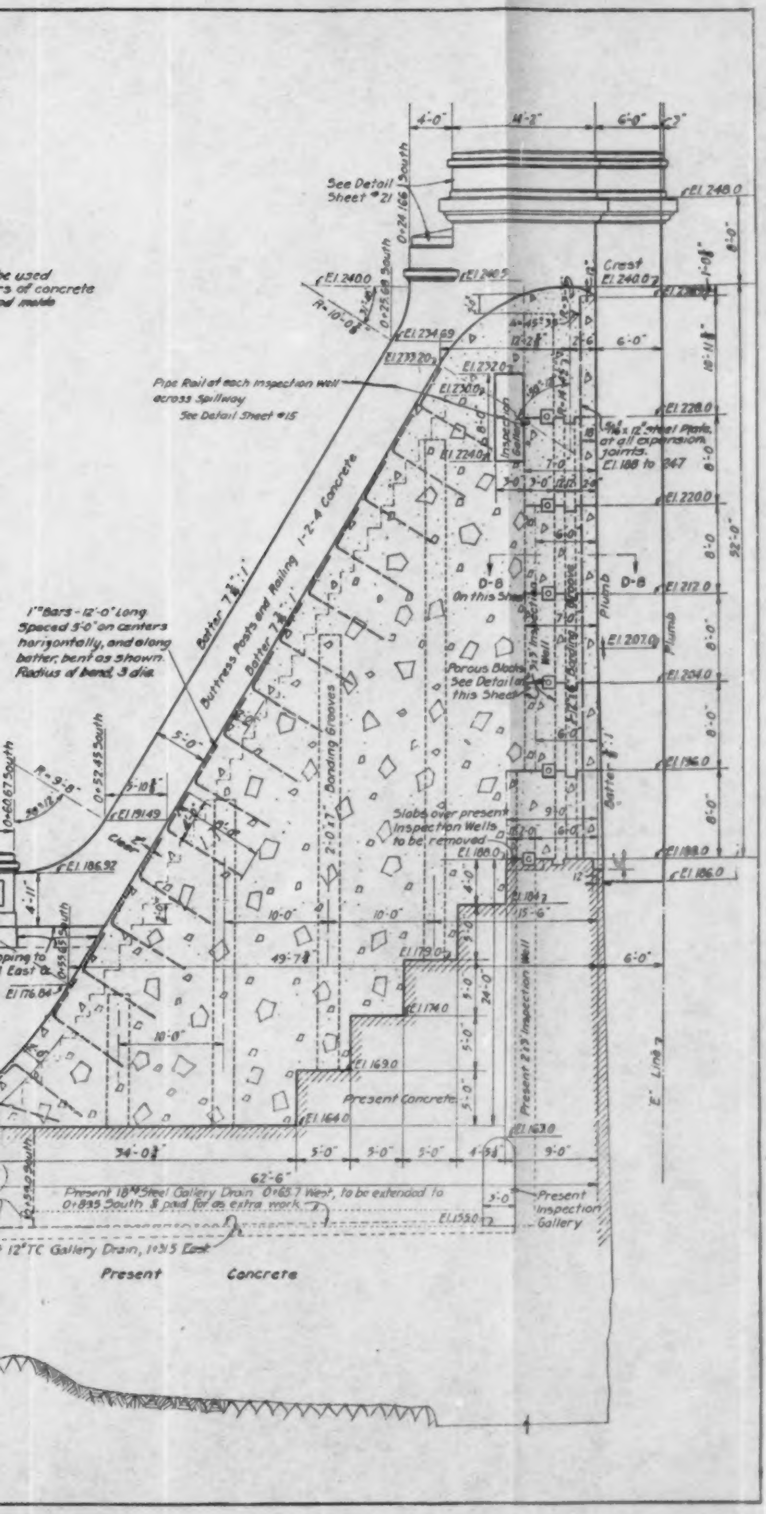
The sand contained a maximum of 10 per cent of clay which was twice the amount authorized by the specifications. It was accepted only after thorough tests were made. One to three mortar briquettes showed an average of 250 pounds per square inch, which is 50 pounds above the standard requirement. At different times, as the work progressed, 4 inch cubes were made from concrete as it passed from the chutes into the dam. The compressive strength of these cubes at the end of 28 days, averaged 1800 pounds for 1-3-6 concrete and 2200 pounds for 1-2-4 concrete. The sand was well graded from small to large and contained a considerable percentage of gravel for which reduction was made in the stone. The clay seemed to lubricate the concrete, causing it to be more easily mixed, chuted and worked. The concrete produced a smaller amount of laitance than is usual and honeycombing is almost entirely absent from the dam.

The stone was taken from the city quarry with no expense other than that of actual quarrying. For each blast, two large well drillers were used to put down about 10 holes 12 feet apart and 85 feet deep, located parallel to and 20 feet back of the quarry face. Three large blasts, each requiring about 4200 pounds of dynamite, made at different times as the work progressed, were required to



LEGEND
Center Line
Section Line
Reinforcement, Light
" , Heavy
Outlines, New Structure
Dotted Lines, New "
Outlines, Existing Structure
Dotted Lines " "
Existing Structure to be removed
Construction Joints.
Chamfer Strips to be used on all exposed corners of concrete except on railings and molds
1-2-4 Concrete
1-3-6 Cyclopean Concrete.
LOCH RAVEN DAM
TYPICAL SECTION OF SPILLWAY
R=39'-10"
58°-12'
See Detail Sheet #21
6'-6"
0+69.17 South
0+60.67 South
0+57.43 South
R=9'-8"
El 186.92
4'-11"
El 182.0
Present Coping to be removed East & West Sides
El 176.84
0+69.25 South
Normal W.S. El 171.2
Present 24" C.I. Gate House Drain
El 168.0
Present 48" C.I. By Pass
El 164.0
Approximate Water Surface with sluice gates open in lower Loch Raven Dam
0+895 South
El 158.0
Class "B" Concrete 0+415 to 0+66.5 & 0+91 to 1+16 West
El 155.0
El 153.0
1+20 South
Present 12" TC Gallery Drain

Fig. 5



See Detail Sheet #21
Crest El. 240.0
Pipe Rail at each inspection well across Spillway
See Detail Sheet #15
Buttress Posts and Railing 1-2-4 Concrete
1" Bars - 12'-0" Long Spaced 5'-0" on centers horizontally, and along batter, bent as shown. Radius of bend, 3 dia.
Bonding Grooves
Porous Blocks See Detail on this Sheet
Slabs over present Inspection Wells to be removed
Present Concrete
Present Inspection Gallery
Present 18" Steel Gallery Drain 0+65.7 West, to be extended to 0+83.5 South & paid for as extra work
12" T.C. Gallery Drain, 1+31.5 East
Present Concrete
Plumb

IG. 5

throw down the necessary 45,000 yards of rock. After each shot, considerable secondary drilling was done by various kinds of drills, and tripod and jackhammer, besides a large amount of mud capping, in order to reduce the stone to stream shovel size. The air used by the drills was piped from the power plant located below the dam. A $\frac{3}{4}$ yard Erie shovel used at the beginning of the job soon proved insufficient and was replaced by a 90 ton Marion shovel for loading the stone into dump cars.

The cars were hauled a half mile to the dam over a 36 inch gauge track by an 18 ton dinkey, 4 cars constituting a train. As the track approached the dam, it was elevated on a trestle at 5.8 per cent grade and dumped directly into a 1500 ton gyratory crusher. A hoisting engine was used to spot the cars up the incline to the front of the crusher, which enabled the locomotive to return for another train while the first trainload was dumped and crushed. From the crusher the broken stone was raised to an overhead bin by means of a belt conveyor. The stone bin has a capacity of 1000 cubic yards and is located between the two sand bins.

Water for the concrete is taken from the river above the dam and measured by two barrels pivoted on their centers and so placed that each will empty into a mixer by hand. Each barrel has a $2\frac{1}{2}$ inch quick opening valve and a mark on the inside to indicate the quantity of water desired.

The sand and stone bins each discharge through a separate chute to a hopper located over a concrete mixer, the hopper being calibrated to measure the quantity of sand and stone required for one batch of concrete and designed to dump all material simultaneously into the mixers. Two one-yard mixers have been used, a Smith tilting mixer and a Ransome non-tilting mixer. For work of this character it developed that the Smith tilting mixer gave better results than the Ransome non-tilting mixer.

The concrete is elevated from the mixers by buckets operating inside of a double wooden tower 204 feet high and distributed by chutes to the desired points. The concrete buckets are raised by engines, one for each bucket, located at the elevation of the highway about 75 feet above the bottom of the lower pit (fig. 5).

The dam is built in 60 foot lengths, separated by transverse expansion joints extending continuously through the cross section. $\frac{5}{16}$ by 12 inch vertical steel plates, placed 18 inches back of the upstream face, are intended to seal the expansion joints. The up-stream

face of the dam is composed of 1-2-4 concrete placed in 8 foot lifts extending alternately 6 and 7 feet back from the face. The remainder of the section is composed of 1-3-6 concrete. The following concreting procedure generally was followed:

First, a lift of 1-2-4 concrete, 60 feet long between expansion joints was deposited. After twelve hours, the forms were removed and 1-3-6 concrete was then deposited in one operation from the back of the 1-2-4 concrete to the down-stream face and for a full length between expansion joints. The 1-3-6 concrete was generally brought 1 foot higher then the 1-2-4 concrete. The two grades of concrete thus break joints both horizontally and vertically and the only vertical joints, except the expansion joints, are those between the two grades of concrete.

A 6 by 12 inch horizontal bonding groove, 2 feet back of the front face and a 14 by 14 inch porous block drain 2 feet further back from the face were placed in the 1-2-4 concrete at the completion of each lift. The bonding groove and groove for the tile drain were cut out by hand as soon as the concrete had sufficiently hardened. The ends of the tile drain are covered with burlap dipped in tar, and the space between the tile and groove filled with dry sand. At each expansion joint, the porous drain enters a 3 by 3 feet well, extending vertically upward and downward to galleries respectively above and below the highest and lowest horizontal joints, by means of which inspection can be made of the seepage through the dam. The lower gallery is drained into the tail water on the downstream side. Vertical bonding grooves 2 feet wide by 7 inches deep and 10 feet apart, bond the masonry across the expansion joints.

The 1-2-4 concrete shown on the plans for the downstream face was omitted and 1-3-6, deposited as described above, was substituted. The placing of forms on the downstream face presented a problem. There was no way of supporting them from the interior without leaving considerable timber in the concrete, and supporting them from the outside would have been expensive. The problem was solved by wiring the forms to dowels inserted in the existing concrete. A few props held the forms in place ready for pouring. As the concrete was deposited, the pressure soon became sufficient to keep the forms from collapsing, and the props were then removed. It was necessary to drill holes in the old foundation concrete for the dowels, but above that elevation, at the end of each day's pour, as soon as the concrete had set sufficiently, pieces of scrap pipe were put in place to serve as dowels.

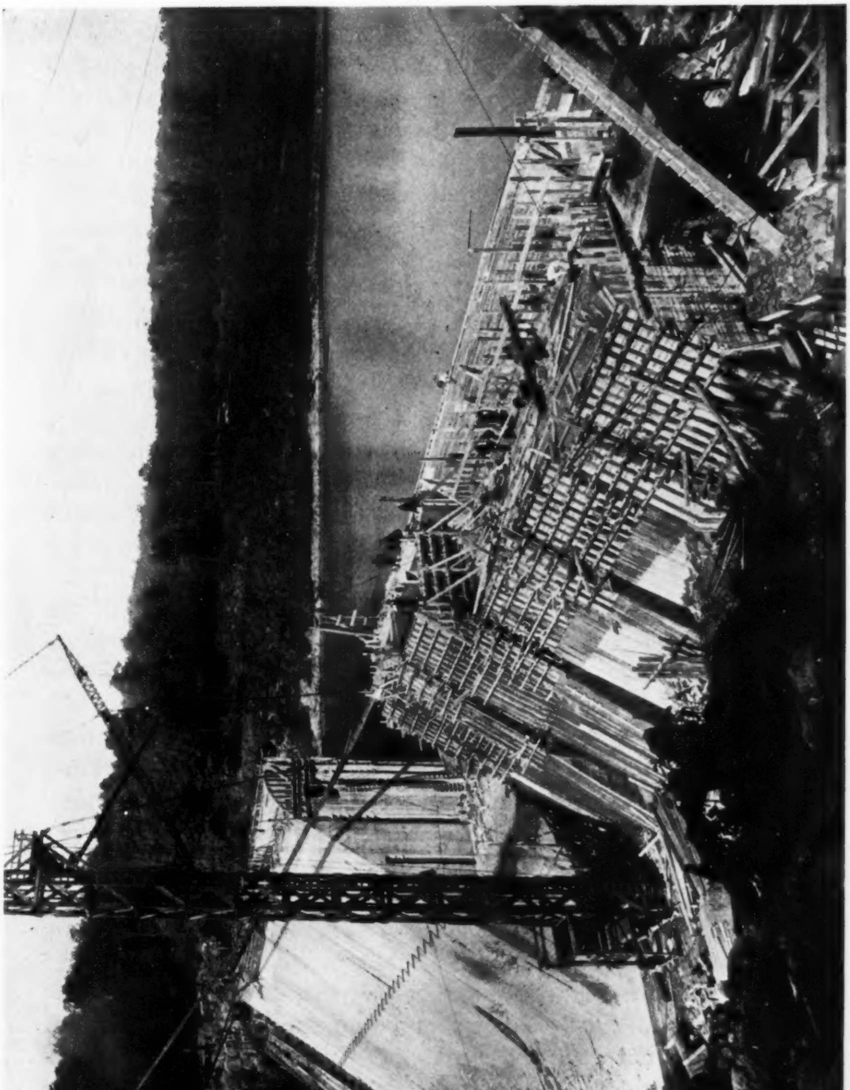


Fig. 6

In the gate chamber one 24 by 24 inch and eleven 6 by 3.5 feet gates were placed. The specifications provided that all gates be securely blocked and fastened in position before concreting. The gates will be operated by stems varying in length from 50 to 75 feet and were required to be set exactly plumb; but as each gate weighs 4700 pounds, it was practically impossible, with the means available, to sustain them in place while concreting around them. In construction therefore, the bolts for the gate frames were set as the concrete was deposited and the gates and gate frames were set after concreting of the gate chamber was completed.

The rock stratification on the east hillside is so much inclined from the horizontal that it was impossible to expose a large face without causing a rock slide. It was possible, however, by stepping the foundation to keep a rugged wall of rock against which to place concrete. About 2000 yards of solid rock were estimated, but owing to the sliding tendency, over 5000 yards were excavated. Excavation for the east abutment was started before completion of the construction plant, yet, due to the difficulties encountered, this portion of the dam was the last completed.

In order to convey concrete from the mixers on the west side of the river to the easterly part of the east abutment, the concrete was rehandled at the east tower. An elevator bucket within the tower was filled from the line chute, then elevated, and the contents emptied into a second chute higher on the tower. The east tower is 168 feet high and the west tower 204 feet high. The towers are 340 feet apart and connected by a $1\frac{3}{4}$ inch cable which carries the concreting chute.

The capacity of the plant is about 600 cubic yards of concrete per 10 hour day, although at times 700 cubic yards have been placed in the same time. The average per working day was 300 cubic yards. A considerable portion of the contractor's plant had been used before, but the loss due to breakdowns was not excessive. The records of the Resident Engineer show a loss of 483 working hours. Of this time 48 per cent was due to breakdowns and other troubles with the mixers, 22 per cent to changing and clogging of chutes, 14 per cent to accidents in the towers and 15 per cent to lack of forming space and other causes. On the whole the work progressed with rapidity, which was due in part to the hearty coöperation between the contractor and the engineers.

About 45,000 yards of concrete are required under the present contract, and the cost of all items will amount to about $525,000. The principal unit prices are as follows:

Loose rock excavation	$4.69 per cubic yard
Solid rock excavation	6.67 per cubic yard
Concrete for balustrades	20.60 per cubic yard
1-2-4 mass concrete	11.85 per cubic yard
1-3-6 mass concrete	10.34 per cubic yard
Steel reinforcement	0.04¾ per pound

50,800 cubic yards of 1-2.5-5 and 1-2-4 concrete were placed under a previous contract, the cost of all work under which amounted to $527,000. The total cost of the dam from bottom to top is therefore, $1,052,000.

The writer is indebted to Mr. C. K. Allen, Resident Engineer, for a portion of the information contained in this article.

THE USE OF CHLORINE TO ASSIST COAGULATION[1]

By Robert Spurr Weston[2]

Because of the limited time allowable, the omission of historical references is necessary but this paper cannot be given without reference to Mr. Arthur L. Gammage's[3] paper in the *Engineering News-Record* of September 7, 1922, entitled "The Prechlorination-Alum Treatment of Soft, Colored Waters." This article is worth more than a casual reading as it contains the results of numerous laboratory experiments and of several years of experience with water purification plants supervised by the writer's firm. This paper is written, therefore, with the hope that the results given by Mr. Gammage will receive more attention by plant operators.

Experience at Exeter, N. H.

The Exeter purification plant was built in 1906 to treat the water stored in an unstripped impounding reservoir which flooded several peat bogs and banks and bottom of boulder clay. The water is of the peaty type,—soft, colored, sometimes turbid, and always difficult to treat even with good mixing and an unusually long period of coagulation. The difficulties were increased following the raising of the reservoir dam in 1909 and again in 1916, thereby flooding additional unstripped areas. The average analytical results during 1913 when the water was treated with an average of 32.6 parts of sulfate of alumina per million, nearly 2 g.p.g., are given in table 1.

Owing to the difficulties in operation, namely the choice between the evils of under-coagulation with inadequate purification or over-coagulation with corrosion, the accumulations of slimy coatings and mud balls in the filter sand, the high percentage of wash water and the at times unpleasant vegetable taste of the filtered water, various expedients were tried.

[1] Presented before the Chemical and Bacteriological Section, Detroit Convention, May 25, 1923.

[2] Weston and Sampson, Consulting Engineers, 14 Beacon St., Boston.

[3] Chief Chemist, Weston and Sampson, 14 Beacon St., Boston, Mass.

The plant was designed with wide allowances and operated at a low rate. In 1913, the wash water supply was increased and an air-washing system installed. Still the difficulties prevailed, and in November of that year, they were unusually great. By treatment with alum alone, coagulation was poor, mud balls were troublesome and the color was reduced insufficiently. It was decided, therefore, to apply chlorine in the form of bleaching powder, mixed directly with the alum, and fed through the same apparatus. Accordingly, in December 1913, bleaching powder was sent to Exeter, and on January 12, 1914, Mr. Gammage was sent there to determine the proper dosage.

TABLE 1

Average results of analyses of samples of reservoir water and filter effluent at Exeter, N. H., 1913

DETERMINATION	PARTS PER MILLION	
	Reservoir water	Filtered water
Cold odor	1.0 veg.	0
Hot odor	3.0 veg.	2.0 veg.
Turbidity	16.0	3.0
Color	80.0	27.0
Oxygen consumed	8.23	3.75
Free ammonia	0.050	0.083
Albuminoid ammonia	0.306	0.159
Nitrites	0.000	0.001
Nitrates	0.13	0.12
Chlorine	4.90	5.12
Hardness by soap	27.5	33.6
Alkalinity	16.9	12.4
Residue on evaporation, total	79.0	80.0
Iron	0.84	0.30
Bacteria at 20°C	408.0	39.0
Bacteria at 37.5°C	193.0	32.0
B. coli, presumptive	4 out of 6 positive	0
B. coli in 10 cc	0	0

At first, the bleach, mixed with sulfate of alumina solution, was applied in amounts equivalent to 1 part of available chlorine per million. Later the dose was reduced to less than 0.6 p.p.m. It was found that the addition of 0.7 part of chlorine per million effected the following change in the character of the effluent:

Subsequently chlorine gas was substituted for bleach, and the average dose decreased to 0.6 p.p.m. or less. This has been the only modification in eight years. However, the better purification decreased the amount of organic matter in the effluent and consequently the amount of matter accumulating on the insides of the services. To reduce the increasing corrosive effect, soda was added whenever the alkalinity was low, thereby decreasing the concentration of hydrogen ions. Soda was first added to the reservoir water, but with the realization of the fact that the best condition for the coagulation of color is one of low pH value, and that for the prevention of corrosion one of high pH value, the treatments were separated. Alum and chlorine are now added to the raw water, and soda when it is necessary, is added to the effluent.

TABLE 2

Significant results of analyses of filter effluent with and without the use of chlorine

	PARTS PER MILLION	
	December 30, 1913	February 3, 1914
Chlorine added	0	0.7
Turbidity	2.0	1.0
Color	15.0	1.0
Oxygen consumed	3.68	1.88
Nitrogen as albuminoid ammonia	0.170	0.034
Nitrogen as nitrites	0.000	0.000
Iron	0.22	0.10
Increase in chlorine	0.00	0.28
Bacteria per cc. at 20°C	45.0	6.0
Bacteria per cc. at 37.5°C	6.0	1.0

Subsequently, Mr. Gammage made the experiments at Belfast, the results of which have been published, and the process has been applied by our firm at the Acadia Mills and elsewhere. It has also been used by Mr. Caird at Rensselaer. Recently Mr. Howard has published the results of similar work at Toronto.

GENERAL OBSERVATIONS

In 1913, the average engineer concerned with the problem of purifying a colored water with a low alkalinity would have used large doses of alum with enough alkali to insure an alkalinity of

8 to 10 p.p.m. in the filtered water. In other words, he would increase the color absorption by increasing the bulk of the precipitate. In the writer's mind at least, there was little thought of the bearing of ionic concentrations upon the problem.

It was understood, however, that color was colloidal and of two kinds, charged negatively and positively, respectively. Obviously, the positively charged color particles would not be coagulated readily by the positively charged hydrate particles and treatment with alum would remove the negatively charged color completely and only part of that positively charged. It is also known that freshly dissolved vegetable color, of which the Exeter water contained much, is not so readily coagulated as was the color dissolved from an old peat bog, and his idea was that chlorine might age the fresh color bodies by oxidation, or, as it was unscientifically expressed at the time, harden the vegetable matter so that it could be coagulated by alum.

We may now make a better explanation of this empirical process which works to save coagulant and wash water, to reduce the color of the effluent and also the accumulations of slime in the filter beds and to lengthen the period between washings. Apparently the addition of chlorine decreases the pH value without lowering the alkalinity and saturates organic compounds, changing their physical states, and thereby making them more easily precipitated by metallic hydrates.

There are many plants where this process might be used with advantage, especially those which treat waters of high vegetable and color contents. Chlorine treatment of these waters before coagulation would reduce the amounts of unsaturated organic compounds in the effluent, thereby reducing the liability to the formation of odors and tastes due to compounds between the organic matter in the effluent and the chlorine used to disinfect it after filtration.

Since the war, there has been a tendency to economize on coagulant, to be satisfied with a lower degree of color removal and to place more reliance upon chlorine to make the water safe for drinking. In some of these cases, complaints because of odors and tastes in the filtered water have arisen where no complaints arose during the period when larger doses of alum were used. In others, more effort has been required to keep the sand beds free from accumulations of organic matter. The writer therefore suggests that

the application of as much chlorine to the raw water as the organic matter will absorb, might effect a considerable saving in coagulant over that required to remove most of the color, besides greatly reducing the amount of organic matter remaining in the filtered water and readily combined with chlorine.

It would seem that the principal reason why chlorine has not been applied to the raw water more frequently is because more perfect disinfection can be obtained by the application of smaller doses of chlorine to the filter effluent. This is, of course, true and in some cases it is also true that more chlorine has been added to the raw water than the organic matter would absorb. It is generally true, however, that if a dose of chlorine only large enough to just saturate the organic matter be added to the raw water, the resulting effluent after treatment with alum and filtration, will contain much less organic matter than if pretreatment with chlorine were omitted, and furthermore, it will require less chlorine for disinfection than if none of this element were added to the raw water.

In reservoir waters treated with copper sulfate to kill algae, it is often wise to add chlorine before filtration to insure the destruction of the odoriferous compound set free at the death of the organism. Dr. Hale has employed this principle for treating waters which are not filtered, and it should be no less useful where filters are employed.

The empirical methods of water treatment are becoming antequated rapidly, but there are some who still cling to them. The work of members of this Association has demonstrated some of the conditions, especially ionic conditions, under which coagulation is at its optimum. Some of these are the presence of free carbon dioxide and a low pH value for a complete precipitation of aluminum hydrate and a high pH value to render effluents less corrosive. To these, in the writer's opinion, should be added the use of chlorine to oxidize or saturate certain organic compounds which otherwise are not readily coagulated by sulfate of alumina alone.

THE VALUE OF COMPREHENSIVE WATER SUPPLY INVESTIGATIONS[1]

By Alex Van Praag, Jr.[2]

Perhaps no one element is more directly responsible for the uneconomical operation and high maintenance costs, and the ultimate failure and abandonment of municipal waterworks stations, than is the failure to conduct a comprehensive and systematic study of the community's water resources prior to the construction of the waterworks system. By a comprehensive and systematic study of the community's water resources is meant a thorough knowledge of the available sources for a water supply development, together with a reasonable understanding of the possibilities of the chosen source of supply with respect to future extensions and enlargement; and also a complete analysis of the relative costs of developing the available sources of water supply, including operation and maintenance costs. The object of this paper is to discuss the value of such preliminary studies insofar as they apply to shallow ground water sources.

That an accusation of this character is based upon sound facts and is just is evidenced by the substantial number of municipalities which from time to time entirely abandon one source of supply in favor of a newly located source, not infrequently in close proximity to the original or former source of supply.

It is manifest, if the above mentioned preliminary studies are to be made, that one of the first and most vital determinations in the study is an assembly of the facts concerning the water bearing strata. Now, throughout certain sections of Illinois the nature of the geological structure is relatively well known and the records thereof are reasonably complete. For example, in most of our northern counties it is reasonably certain that an ample water supply of good quality is readily obtainable if wells are drilled to

[1] Presented before the Illinois Section meeting, March 21, 1923.

[2] Member of Holbrook, Warren, and Van Praag, Consulting Engineers, Millikin Building, Decatur, Ill.

St. Peter or Potsdam Sandstone. In such a case a preliminary study requires no extensive prospecting or test drilling to determine the local geological structure, but may be considered primarily, if not solely, for the purpose of ascertaining the type and probable cost of any proposed installation.

In other sections of Illinois, however, the prevailing conditions are decidedly different. In Central Illinois, for example, the major number of our public water supplies are derived from shallow ground sources, more generally from water bearing glacial drift deposits. The records of drillings in one community are of little, if any, value to a neighboring community, and in general the records themselves are very meager. Moreover, the glacial drift is peculiarly irregular and non-homogeneous and there is no certainty in securing any appreciable volume of water until extended drillings and pumping tests have been made. Under these conditions the preliminary studies in connection with a proposed water supply installation are of grave importance, for on their thoroughness depends not only the possibility of the installation from a financial standpoint, but the feasibility of any installation being made at all. Still further, the reliability and operating success and the cost of maintenance in such cases are entirely dependent upon the action taken as a result of the preliminary investigation.

All too frequently preliminary investigations of ground water supplies are not made at all or they are directed by the unqualified judgment of local persons in preference to being based upon an assembly and study of facts and data best interpreted by engineers experienced in water supply developments. It seems to be the general mistaken impression of public officials that the first available funds should be expended at once for a part of the necessary equipment for the waterworks instead of using the first modest expenditure for investigation to insure the water works installation being a permanent and economical one.

In order to elaborate somewhat on the necessity of preliminary studies and suitable test drillings the author assumes the liberty of referring to, and analyzing, the water supply history of a particular city with which he is personally familiar. It is one which presents a typical case.

Mt. Pulaski is a city of 1510 population. It is built upon the peak of an abrupt hill, one of a few high points in Central Illinois. The surrounding territory is quite flat and the nearest well defined watercourse is approximately 3½ miles distant.

The original waterworks at Mt. Pulaski were installed in 1895 and the source of supply then comprised a single well about 85 feet in depth, penetrating fine sand, and located at the public square on the very peak of the hill. About 1907, only twelve years later, a new waterworks station was constructed in the southwest part of the city, the supply then being derived from three dug wells, penetrating a layer of fine yellow sand of more or less indefinite depth. Each well was 33 feet in depth and was walled with stone. These three wells which are still in service are all located on a single tract of land enclosing about three-quarters of an acre. Another similar well, but with a 23 foot tubular extension in its bottom, was also located nearby and formerly was held in reserve to meet excessive demands, though it later was entirely discarded as a part of the public water supply.

Since their construction these wells have ever been subject to clogging with fine sand thereby reducing their capacities, causing undue wear on pumping equipment, and resulting in exorbitant maintenance costs. Their yields have accordingly been totally inadequate and the cause of a general restricted use of water. The restricted use of water has resulted in a general tendency to depend upon private wells, all of which circumstances, of course, assist in raising the unit operating costs of the public supply.

For some time the city council has realized the necessity of improving the city's water supply resources and during the past year it was prevailed upon by its engineers to conduct a series of test drillings in the hope of locating a more satisfactory source of supply.

The engineers outlined a systematic program of drilling based upon a study of the surrounding topography, assembled records of previous drillings, and a knowledge of the general geological structure in the vicinity, and the drilling program was instituted.

A series of holes were drilled progressively to the east and south along a more or less meandering line lying just south of the city, where the available data indicated a satisfactory supply was most likely to be located. As each test well was drilled samples of the drillings were collected for examination and accurate logs of the wells were drawn. The logs were platted in section to their true elevation along sections drawn through the principal lines of the drill holes, and an accurate plat was made showing the location of each test hole. These data not only served their purpose, during the progress of the drillings, but are now a matter of permanent record.

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A total of 22 test holes were drilled before a supply of satisfactory volume was located and the final location determined for a new pumping station. As a result of the drillings, however, the city has located a water bearing stratum consisting of coarse sand and clean coarse blue gravel approximately 17.5 feet in depth and lying between depths of 40 and 57.5 feet below the surface. The deposit is under a static head of water which rises to within 14 feet of the surface.

Before concluding the test drillings the city conducted a pumping test on a 8 inch well located at the site of one of the test drillings. The test was conducted under the direction of the engineers assisted by representatives of the Illinois State Water Survey and the State Department of Public Health. It included a continuous pumping of the well for about 26 hours, during which time measurements of the well discharge and of the draw-down, both at the well itself and at other nearby points, were simultaneously recorded. It should be noted that, while the drawdown when first pumping the well was marked and rapid, yet with continued pumping the water level gradually assumed a more or less permanent level and at no time was it lowered to the top of the water bearing stratum.

The test data secured indicate that the city can produce from a single well in the vicinity a sufficient supply of water to satisfy its present demand with less than six hours of continuous pumping. Heretofore, the present wells have been exhausted after a relatively short period of pumping and it became necessary to discontinue pumping until they again were replenished, and the supply accordingly has been extremely doubtful at all times.

The total cost to the city for conducting the test drillings approximated $1500 and the city is now having prepared the necessary plans and specifications for a new pumping station. This new pumping station will probably be constructed during the coming year. It makes the third water pumping station to be constructed in a period of twenty-eight years. It is 16 years since the construction of the present station.

It should not be assumed that the Mt. Pulaski stituation is an unusual one and that it did not offer its difficulties during the period of the drilling. As a matter of fact, it was necessary at the outset, in order to satisfy certain members of the city council, to drill two holes on the present pumping station lot. Both of these holes were drilled to more than twice the depth of the present dug wells and

each penetrated but a negligible depth of fine yellow sand, water bearing, and thus showed conclusively that the present location is a most unsatisfactory one.

After sinking some 7 or 8 holes with only moderate success, the city against the advice of its engineers again returned to the present water works site and sunk in the immediate vicinity at least two more holes.

During the course of the drilling it was necessary also to satisfy the demands of certain council members who have a religious belief in the unfailing "water witch." These particular members, it is interesting to note, were able by the use of the "witch" to trace the water bearing strata from one of the test hole locations, after the test hole had been drilled, for a distance of nearly 150 feet towards the old pumping station site. At this point they were forced to discontinue the use of the witch because of severe cold weather and unfortunately the weather has not as yet sufficiently moderated to permit their again bringing out the "witch" for further service.

Now it should be noted that at Mt. Pulaski there were no visible or outstanding assurances of success in locating a satisfactory water supply if the test holes were sunk, excepting the convictions of the engineers who had devoted some time and study to the local situation. To be sure, many of the first holes sunk indicated discouraging results and it was not until the entire 22 holes were sunk that conditions were considered satisfactory to warrant discontinuing further investigations. On the other hand in a similar study at Witt, Illinois, it was found necessary to sink only 5 holes when sufficient data were secured to warrant discontinuing drilling.

It is not of general interest that Mt. Pulaski has experienced particular success in improving its water supply by drilling. The Mt. Pulaski experience is discussed here because it is a typical experience and illustrates the one point the author wished to impress, that is, by a modest expenditure for test drillings and preliminary investigations and by truly studying its water supply resources this city has located a source of water supply sufficient to warrant the abandonment of its present supply in favor of a new one. Had this new supply been properly investigated before the preceding two water pumping stations were installed, it would doubtless have made unnecessary the large expenditure for rebuilding at least twice and would have eliminated largely the relatively exorbitant maintenance costs which have been experienced by the city

for the past 28 years. Many other cities have had much the same history as Mt. Pulaski. Not until the value of thorough preliminary studies is fully appreciated, however, may we expect to eliminate this needless waste of money on waterworks improvements.

As engineers or persons otherwise interested in the proper development of public water supplies it remains with us to exert every effort to assure that future water supply installations will be based upon sound facts and not upon chance judgment. In other words, if we wish to insure proper and economical water supply installations and assist in preventing expensive rebuilding programs, we must impress the responsible officials with the necessity of comprehensive and systematic preliminary water supply investigations by competent engineers.

DISCUSSION

Mr. S. L. Etnyre:[3] I should like to ask Mr. Van Praag what conclusions he drew from the drop of water in the well and the relative drop in well and the test hole (about 150 feet distant) as to the size and adequacy of the underground reservoir supply.

I wish to cite a very remarkable well system in South Omaha, Neb. The South Omaha Stock Yards Company decided to build a water plant of its own and found a very excellent grade of water in the Missouri River bottoms quite near to the river. Tests on a pumpage of about 300,000 gallons per day showed the water level to drop 65 feet during the first hour, but very little drop thereafter. The total quantity of water desired being 4,000,000 gallons per day fifteen 10 inch wells were driven within an area of several acres, and it was found that the water level dropped about the same when pumping from all the wells as from the single well.

Mr. Alex Van Praag, Jr.:[2] When a water supply is derived from wells it is manifestly impossible to conduct a detailed physical inspection of the source of supply to determine its adequacy. We must accordingly resort to the best available known means for determining such data. In the case of a shallow well supply, the two fundamental elements in determining the adequacy are, first; a determination of the storage volume of the water bearing strata, and second; an understanding of the source and manner of replenishing the available storage and its ability to replenish the demands made upon the storage reservoir. The former element may be satisfac-

[3] Superintendent, Water Works, Council Bluffs, Iowa.

torily determined by conducting extensive drillings to locate the limits of the water bearing strata and by examining the character of the water bearing strata to determine their volume of voids. The latter element, in the case of a shallow ground water source, is substantially dependent upon the rainfall and the watershed area above the well locations, which factors are relatively easily determined. These data, substantiated by a study of the results of an extended pumping test, afford the best known means of determining a supply's adequacy.

In the case of Mt. Pulaski we conducted a series of test drillings and we had a fair knowledge of the limits of the water bearing stratum and its character and accordingly we calculated its probable storage capacity as being far in excess of the demand between periods of replenishment. We also knew that the watershed area above the wells was a considerable number of square miles and was amply able to replenish the storage basin from year to year with ordinary percolation from the rainfall over the watershed area. In addition to this we conducted an extended pumping test following a period of drought and after a few hours pumping we were unable appreciably to alter the water level in the well, indicating that continuous pumping at the rate necessary to supply the city's demands had little affect, if any, upon the vast storage volume available.

These data, gathered by the best known available means of determining a well water supply's adequacy, we believe justify our conclusion that the proposed new supply will be adequate.

THE WATERS OF NORTH DAKOTA

By A. E. McCoy[1]

At various times numerous calls have been received in the Public Health Laboratory for data upon that very interesting subject, the water supply of North Dakota. An immense amount of material has been accumulated during the period these laboratories have been in operation. Perhaps the most work done was by Dr. Gustav F. Ruediger during his term of office as Director of laboratories and the material he collected has been used, together with a great deal of data accumulated since, in the preparation of this paper.

The rivers of the state contain a palatable water and need very little treatment to render them quite safe for drinking purposes, but most of them are very hard. The same cannot be said of the well waters. Throughout the whole of the state, shallow wells, none deeper than 20 feet, yield a fairly palatable water, but artesian and deep wells, as a rule, yield a highly mineralized water. In order to find a standard with which to compare the waters of this state and to decide which is a good water and which is the opposite, the standard fixed by the Secretary of the Treasury for the chemical purity of waters used on interstate trains has been adopted. The amounts are expressed in parts per million and can be converted into grains per gallon by multiplying by 0.058:

	GOOD	FAIR	POOR	BAD
Total solids	Up to 1,000	Up to 1,500	Up to 2,000	Any-
Chlorine	Up to 250	Up to 800	Up to 1,200	thing
Sulphate radicle	Up to 250	Up to 600	Up to 1,000	over
Magnesium	Up to 75	Up to 125	Up to 175	these
Carbonates	Up to 50	Up to 100	Up to 250	figures
Alkalinity	Up to 500	Up to 800	Up to 1,200	

Many of the waters placed in the "fair" class or in the "poor" class have only a temporary effect upon the people using them and

[1] Formerly Chemist, State Public Health Laboratories, North Dakota. Deceased.

the body soon develops a tolerance for them. Stock which has been reared on such water is slow to drink water which is in the "good" class. At the same time, however, horses are said to suffer various disorders when subjected to waters with high chlorine and sulphate content. When selecting a water for municipal supply every effort should be made to find one that meets all requirements for the class called "good" and does not have a hardness exceeding 400 parts per million. Its bacterial content should also be considered, for, while the water may pass muster chemically, if it be above standard bacteriologically, the cost of treatment has to be considered.

The suitability of a water for boiler use has also to be considered. It has been found that there are no good, untreated, boiler waters in the state, the porportion of lime, magnesium or iron being so high that the formation of incrustants renders them very unsuitable. For this reason the Great Northern has installed water softening plants throughout its lines from Devils Lake west.

The artesian wells in the Red River Valley yield water that is quite salty to the taste and very hard. Practically every water analyzed contains more than 2000 parts per million of total solids and over 1200 parts of chlorine. These waters are used for every purpose apparently without bad effects. The deep wells, which do not flow, often contain very good water especially in Cass and Richland counties.

The shallow well water of the Red River Valley is, as a rule, less highly impregnated with mineral salts than that of the deep wells, except perhaps, in the northern part of the state, where throughout Pembina, Cavalier, Walsh and again in Trail counties the underground shallow wells are quite salty in taste. If the soil is sandy the waters may have a hardness of 500 parts or less, but their bacterial count is likely to be high, especially if the wells are not properly protected. The shallow well waters classed as "bad" contain large amounts of Epsom salts which give the water a bitter taste and are irritating to the intestine.

The deep well waters in the central plains are somewhat better than those in the Red River Valley, being lower in solids, hardness, and sulphates but higher in alkalinity. Even at that, however, they are considerably above what is considered a suitable water. The flowing wells are not very common except in the southern tier of counties. The wells here are very deep and the waters highly mineralized and uniformly hard. All are very high in sulphate or

chloride. The shallow wells of this region are softer and lower in magnesium compounds than those of Red River Valley, but, when compared with the deep well waters, they are harder and higher in magnesium salts. The best shallow wells are found in Pierce, Benson and Nelson counties.

In the western part of the state, or Missouri plateau region, flowing wells are very scarce except at the north and south borders of the county. These waters are very soft, but have a high alkalinity due to bicarbonates. The deep well waters are also high in alkalinity and have a high mineral content and can be used with some satisfaction as boiler supply.

Compared with the deep well waters of the Red River Valley they have a higher alkalinity and are more highly mineralized, but have not such a great degree of hardness. Compared with those in the central part of the state they have a higher alkalinity and hardness content, but not so much chlorine or sulphates.

The shallow wells in this part of the state are the least mineralized of anywhere and for this reason may be classed as good boiler waters.

To go into the subject a little more particulary, the records of chemical analyses made at the main office of the Public Health Laboratories have been gone over and the results of 96 examinations made from January 1, 1917, to February 14, 1920, have been studied.

The principal visible water supply of the Red River Valley is the Red River. This source is used by Wahpeton and Fargo and as an auxiliary supply for Grand Forks. The water, owing to its hardness, turbidity and high pollution is softened, settled and chlorinated. The Fargo analysis may be taken as an example:

Total solids	179
Alkalinity	113
Chlorine	7
Sulphates	31
Carbonates	32
Magnesium	97

Comparison with our standard shows that this water contains too high a hardness radicle. It is interesting to compare also the water of the Goose River used by Mayville:

Total solids	918
Alkalinity	251

Chlorine	26
Sulphates	390
Carbonates	251
Magnesium	390

This water, owing to its high mineral content, is practically unfit for any purpose whatever. Even plumbing fixtures are attacked.

Nine well waters of varying depths have been examined, which have been scattered throughout this region. It is difficult to single out any one as distinctive for the region as they vary so much in total solids, chlorine content and hardness. However, we will give the figures for a well at Drayton:

Total solids	20,922
Alkalinity	236
Chlorine	9,384
Sulphates	988
Carbonates	23
Magnesium	256

and the well in the park at Mayville:

Total solids	3,362
Alkalinity	219.3
Chlorine	773.7
Sulphates	649.8
Carbonates	568.6
Magnesium	281.2

All these waters are high in sulphates, alkalinity and magnesium compounds. They have more or less of a "salty" taste and are high in incrustants.

Of waters from the central plains some 18 localities have contributed 38 samples. These are all well waters, many being taken from several sources in one locality in an endeavor to find the most suitable supply for a waterworks installation. The latter samples being from Jamestown, Langdon, Lakota, Leeds, Fessenden and New Rockford, which furnish rather a good selection for comparison. A study of the average analysis of 4 samples of Jamestown water taken from different wells shows the following:

Total solids	754
Alkalinity	359
Chlorine	42
Sulphates	421
Carbonates	105.8
Magnesium	179.2

Comparing this with our standard we see that the mineral content puts these samples in the "fair" class, if not in the "poor." Going to the opposite end of the state we may examine the Langdon waters where some 10 samples were tested to determine which would yield the most suitable water for a city supply. The average of the analyses is as follows:

Total solids	1,157
Alkalinity	266.5
Chlorine	177.8
Sulphates	379.6
Carbonates	132.8
Magnesium	80.2

Comparison with our table shows this to be a fairly good water. In fact the water in use now at Langdon is of good quality, but contains enough iron to cause a noticeable taste and odor when it stands in the pipes or is heated.

It might also be interesting in this connection to consider the water as found at Fessenden, which is placed in about the centre of this section of the state. In searching for a satisfactory water supply for this city 5 representative samples were examined. These yielded results as follows:

Total solids	1,342
Alkalinity	540.5
Chlorine	182.3
Sulphates	340.3
Carbonates	284.2
Magnesium	51.2

The waters from this region, therefore, can be placed in the "good" class, except that they need softening. It is difficult however to say positively just how each of the many samples in this region compare with each other, but the northern group of waters, while very "salty" in taste, and so unfit for drinking, are often quite soft.

In the Missouri Plateau section, beside some 24 wells, we should consider also the Missouri river which is used by Williston, Mandan and Bismarck. The water from this source is very turbid and highly polluted so that these cities have installed complete treatment plants, such as sedimentation, chemical treatment, filtration, (except Bismarck and Mandan) and chlorination. The untreated river water in several examinations taken at Williston and Bismarck usually tests as follows:

Total solids	662
Alkalinity	368
Chlorine	29
Sulphates	161
Carbonates	125
Magnesium	164

This shows that the river water is of moderate hardness and can be made a very suitable source of supply.

The well waters of this region are more or less colored with vegetable matter owing to the whole district being underlayed with lignite deposits. Several of the wells yield a coal black water which when treated with a coagulant, is quite satisfactory. Such a water is found at Scranton in Bowman county in the southwest corner of the state. Seven samples of varying duskiness have been analysed from this town with the results as follows:

Total solids	1,253
Alkalinity	453.1
Chlorine	22.4
Sulphates	417.8
Carbonates	318
Magnesium	157.1

This places these waters in the "fair" column, but shows them inclined to be hard.

The waters in the northern part of this section should next be considered and these comprise samples from Crosby, Berthold, Minot, Kenmare and Stanley. A synopsis of these analyses is as follows:

Total solids	2147.1
Alkalinity	709.7
Chlorine	38.4
Sulphates	625.2
Carbonates	625.3
Magnesium	142.1

It will be noticed that these waters come in the "poor" class, which is all too true with the exception, perhaps, of Minot. Here we have a water that has some color and a pleasantly salty taste, but is of very good quality otherwise and one of the two city wells is quite "soft." All these samples contain iron in such quantities as to stain porcelain or enamel ware.

TABLE 1

PLACE	POPULATION	WATER SYSTEM	SOURCE SUPPLY	TREATED	STAND PIPE	DIRECT PUMPAGE	GALLONS USED PER DAY IN THOUSANDS	SEWER SYSTEM	STORM SEWER SEPARATE	SEWAGE TREATED	METHOD	PER CENT POPULATION SERVED
Anamoose........	700	Yes	Well	No	Yes	Yes	10	Yes	No	No	†	32
Bismarck........	7,161	Yes	River	Yes	No	Yes	500	Yes	No	No	†	50
Carrington.......	1,500	Yes	Well	No	Yes	Yes	?	Yes	Yes	Yes	Septic tank	60
Devils lake......	5,200	Yes	Well	No	Yes	Yes	250	Yes	No	Yes	Septic tank†	50
Dickinson........	4,100	Yes	7 wells	No	Yes	Yes	175	Yes	No	Yes	Septic tank†	65
Enderlin..........	1,919	Yes	3 wells	No	Yes	Gravity	50	Yes	No	Yes	Septic tank†	65
Fargo.............	23,000	Yes	River	Yes	No	Yes	2,300	Yes	No	No	†	90
Grand Forks.....	14,000	Yes	River	Yes	No	Yes	890	Yes	No	No	†	90
Grafton..........	2,500	Yes	Well	No	Yes	Yes	?	Yes	No	Yes	Septic tank	75
Garrison.........	714	Yes	2 wells	No	Yes	Yes	?	Yes	No	No	†	83
Hillsboro........	1,183	Yes	Well	No	Yes	Yes	6	Yes	No	No	†	50
Hazen............	600	Yes	Well	No	Yes	Yes	?	Yes	Yes	Yes	Chemical†	10
Harvey...........	1,492	Yes	River	No	Yes	Yes	60	Yes	No	No	†	25*
Jamestown.......	6,627	Yes	Well	No	Yes	Yes	450	Yes	No	Yes	Septic tank†	75
Kenmare.........	1,543	Yes	Well	No	Yes	Yes	?	Yes	No	No	†	66
Larimore.........	1,039	Yes	Well	No	Yes	Yes	?	Yes	No	No	†	30
Lidgerwood......	1,100	Yes	6 wells	No	No	Yes	?	Yes	No	Yes	Septic tank†	100
Langdon.........	1,228	Yes	2 wells	No	Yes	Yes	20	Yes	No	No	†	75
LaMoure.........	1,009	Yes	Well	No	Yes	Yes	50	Yes	No	No	†	95
Lisbon...........	1,655	Yes	5 wells	No	Yes	Yes	30	Yes	No	No	†	80

Mayville	1,218	Yes	River	No	Yes	Yes	70	Yes	No	Yes	Cess pool†	50*
Marmarth	1,460	Yes	2 wells	No	Yes	Yes	20	Yes	No	No	*†	65
Mandan	3,873	Yes	River	Yes	No	No	133	Yes	Yes	No	†	75
Minot	12,000	Yes	2 wells	No	Yes	Yes	300	Yes	Yes	Yes	Filter beds†	80
New Rockford	2,200	Yes	4 wells	Softened only	Yes	No	50	Yes	No	Yes	Septic tank†	40
Oakes	1,637	Yes	18 wells	No	No	Yes	166	Yes	No	No	†	95
Stanley	591	Yes	2 wells	No	Yes	Yes	5	Yes	Yes	No	†	40
Velva	835	Yes	Springs	No	Reservoir	Yes	30	Yes	No	No	†	80
Valley City	5,136	Yes	Well	No	Yes	Yes	265	Yes	No	No	†	85
Williston	4,278	Yes	River	Yes	Yes	Yes	?	Yes	No	No	†	98
Wilton	1,025	Yes	4 wells	No	Yes	Yes	25	Yes	No	No		25
Wahpeton	3,000	Yes	River	Yes	Yes	Yes	300	Yes	No	No	†	100
Cooperstown	1,019	Yes	Well	No	Yes	Yes	?	Yes	No	Yes	Septic tank	Just completed
Hankinson	1,503	Yes	2 wells	No	Yes	Yes	?	Yes	No	Yes	Septic tank	Under construction.
Leeds	682	Yes	Well	No	Yes	Yes	10	Yes				Just completed†
McVille	350	Yes	Well	No	Yes	Yes	10	Yes	No	Yes	Septic tank†	Just completed

*Not used for drinking.

†Discharge into river, wet coulee or lake.

This report would not be complete without reference being made to the spring waters. These are located in Grand Forks, Trail and Stutsman counties together with a group along the Missouri slope (7 samples in all). Springs occur at Inkster, Northwood, Hatton in Grand Forks county and, with perhaps one exception, yield a very good sample of water from a chemical standpoint. The springs near New Rockford and at Jamestown also yield excellent water. Three springs near Williston, recently examined, are also found to be in the "good" class.

The Federal Government is conducting an investigation into the question of "stream pollution" and on the receipt of a request from Mr. R. E. Tarbett, Associate Sanitary Engineer, United States Public Health Service, a questionnaire was sent out to all the cities and towns in the state possessing water and sewer systems to ascertain what disposal was made of sewage in this state. Replies were received from thirty-six points. These have been arranged in table 1.

A study of this table shows only 9 places which get their water from a visible source, 8 from rivers and 1 from springs. Six of the 8 river supplies are treated with a coagulant and chlorine, the other 2 use the water for sanitary purposes only, while water for drinking, washing clothes and cooking is obtained from melted ice, cisterns or shallow wells.

In regard to sewage disposal, 27 discharge their sewage into the river, lake or coulee untreated, 9 give a preliminary treatment with some form of septic tank. Only 1 city in the state, Minot, has installed a modern sewage treatment plant and this was in operation in the summer of 1921. The other places discharge into a low place or dry coulee.

Some attempt is made to soften the river water in Fargo and Grand Forks. New Rockford has just installed a softener for its well water supply and Mayville is considering such an improvement.

In conclusion, it may be said that, while some attempt is made to prevent stream pollution, our larger cities, except one, are doing nothing in that respect. It will be only a matter of time before they will be compelled by law to abate the nuisance which their untreated sewage will create for communities situated below them.

THE CONDITION OF THE MINOR PUBLIC WATER SUPPLIES IN IOWA[1]

By H. V. Pedersen[2]

Whenever any one starts out to put the blame of something on somebody, he immediately lays himself wide open to criticism. It is not my intention however to pick out only the worst conditions and then blame certain individuals for them. It is my intention to discuss in a general way the conditions, both good and bad, and to point out the possible reasons why these conditions exist.

There are approximately 900 incorporated cities and towns in the state of Iowa. Of these, 15 belong to the first class, 92 to the second, leaving approximately 800 that may be put into a third class. Out of this total of 800 third class towns only 400 have public water supplies, which we here classify among the minor water supplies of the state. It may be well to remark here that there are still over 400 incorporated towns in Iowa that have no form whatever of public water system.

These small town public utilities, commonly known as a water works system, are composed, as all systems are, of two factors. The one factor is the distribution system, consisting of pumps, pump-house, water mains and storage or pressure reservoirs. The other factor is the water that is distributed through the distribution system and the source from which that water is obtained. The one factor is as essential and important to a good water system as the other, for what good is a distribution system to a community unless there is a good supply of water available, or available water with no means of distributing it to the consumer or within reach of the home or business in time of fire? But regardless of how self-evident this seems, inspection of more than 100 of these systems during the past year by the Engineering Department of the State Board of Health has disclosed the fact that there is much room for criticism against certain past practices in the state.

[1] Presented before the Iowa Section meeting, November 2, 1922.

[2] Sanitary Engineer, State Board of Health, Iowa.

In practically every place visited some fault could be found with or some criticism be made of the distribution system. Some towns have outgrown the 4 inch main service and are suffering from inability to bring enough water to a certain place in town in time of fires. Other towns suffer from lack of storage capacity, some from poorly constructed, open reservoirs, and the majority most of all from some poor piece of construction which allows surface pollution to enter the water.

A great deal might be written on the subject of proper size of water mains for minor systems. Fire insurance companies demand more use of 6 inch pipe while past practice has specified very little of that size. There is no question but that some engineers or corporation installing water works systems have in the past placed many miles of 4 inch pipe where 6 should have been laid. No doubt the towns themselves are somewhat to blame as they wished to cut down first costs. No matter who is to blame or what the past theory was, however, it is certain that more thought must be given to the use of 6 inch pipe and the difference in initial cost of the 4 and 6 inch pipe must not be taken into consideration.

Most small towns in Iowa have ample pressure for fire fighting, as the majority of them have elevated steel tower tanks. In some places the tanks are a little too small, but with constant pumping this difficulty is overcome. Some have old pump equipment and old dark, dingy pump houses that need replacing, but, on the whole, without taking the lack of duplication into consideration, the equipment of our minor water supplies is satisfactory. They are not all perfect, although generally they "get by"! The one outstanding feature to be criticised in most of the water works systems is not so much the equipment of the distribution system as the failure to protect the water supply.

The consensus of opinion among many people directly concerned has appeared to be, or you might say that it has been the policy in the past of town officials and engineers, that, if you get a distribution system installed to distribute water, the source of supply will take care of itself. More stress has been and is still being put on the distribution system than upon the supply of water. Much of this opinion is due to the fact that the public and many engineers have failed to take the matter of a safe water supply seriously.

It may seem a little exaggerated to many, but it is a fact that about one-half of the minor water supplies in the state are unsatisfactory.

The majority of these unsatisfactory supplies are shallow wells, although there are a goodly number of deep, drilled wells included which are from 20 to 50 years old. Years ago when these supplies were chosen it was not difficult to get an ample flow of safe water almost anywhere. A well could be sunk and if there was any water at all, that water would most probably be free from surface contamination. Today the location and construction of a well supplying water to our smaller towns is a most serious problem.

One minor supply after another is being reported as unsafe for drinking purposes, when the bacteriological analyses disclose the fact that the water is contaminated by surface pollution. Of all the public water supplies visited by the Engineering Department, where the B. coli group of bacteria were found, it was invariably discovered that the wells were located in the lowest point in the town, where all of the natural drainage may easily contaminate the water. Many towns, which for years prided themselves upon their excellent water supply, are being most heartlessly awakened to the fact that they no longer possess the best water in the state, but that the wells are polluted by surface contamination, are located in entirely the wrong place and, if they continue using the supply without shutting off this contamination, they are subjecting themselves to a greater risk of water born diseases than is desirable.

But if these are the prevailing conditions, who is to blame? In my opinion, I should say that we are all to blame. We have all been too busy talking about the systems in our larger cities and about purification plants and so on and have failed to give much thought to what the smaller communities have. Every engineer in the state, every manager or operator of a water plant, every member of this organization must be made to realize that the problem of securing a safe drinking water in Iowa is becoming more and more serious. Every engineer or corporation that has made a business of designing water works systems should give more thought in the future to the water supplies. Every engineer or water plant operator should impress upon the community that is employing them the importance of first locating a good and safe water supply. If a town is contemplating a water system and has only a limited amount of funds, it is better to spend it on obtaining a good water supply and a portion of a distribution system than to spend it all for a distribution system and have a water supply that is not fit for drinking. All towns with water systems which are having trouble with their water

supplies should be urged, when it becomes necessary to abandon the old supply, not to make the same mistake twice and to locate on a new site that is as bad as the old one.

Often careful thought and experiment are required to determine whether it is best to drill a deep well, to depend on shallow ones, or to use wells at all. Each locality has its own characteristics and difficulties. What might be the best for one town might be entirely wrong for another. The geological formation of Iowa and the mineral deposits are such that no two districts can be treated alike. Because a town in northern Iowa has a good deep well is no reason why a town in southern Iowa should spend all of its money trying to drill one. Every one who has anything to do with water or who claims to know anything about it should urge upon every community the necessity of studying every possible source of water, before a permanent site is definitely decided upon, that a water supply should be chosen only after taking both quantity and quality into consideration, that if two supplies are available and one contains less iron, less sulphate or is less hard than the other, that supply should be given more consideration, even if it is located several miles from the town. There is absolutely no excuse for putting any new well in an improper location.

When making surveys of public water supplies we hear many expressions of how the water has been good for years and years and they cannot understand why it should be bad now. The general public is somewhat confused on the subject of pollution and has been told so many things that it hardly knows what to believe. Even engineers do not all agree on the theory of underground water pollution. Some say that bacteria from seeping privies, barnyards and other sources will pass for long distances through water bearing sands when once they enter it, while other engineers believe this is untrue. I am not going to discuss the problem of underground pollution at this time. However, all engineers and water works men should advocate that all precautions should be taken to locate a water supply and protect the pump installations and valve connections so as to exclude surface waters, since we know that all surface waters of Iowa are more or less polluted and contain bacteria of a dangerous nature.

As the Engineering Department of the State Board of Health is, in a way, the guardian of the water supplies of the state, you no doubt wish to ask what we are doing to better conditions. We are

trying to better conditions, but the department is so small and has so little money to spend that it is impossible to make even a fair showing. Along with the required routine work of the office, it is only possible to investigate about 100 water supplies a year. At this rate it would take five years to cover the state. This year we have so many other things to do in the work of sanitation that it will not be possible even to visit this many. You can all realize that many things may happen to a water supply within 5 or 6 years.

So far, the general public of the state of Iowa, various organizations and the members of the engineering professsion have failed to realize the seriousness of state supervision of the public water supplies and have failed to demand that the state legislature provide such supervision. Several states adjoining Iowa have a division of sanitation with a staff consisting of a chief engineer, 4 or 5 engineering assistants and sufficient office help to carry on the work properly. Iowa, one of the wealthiest states in the union, provides only one engineer and one stenographer to do all of the work of sanitation in the state.

As the sanitary engineer of the state, I wish to urge you men here to give as much thought in the future to the conditions of our minor supplies as you have to the major and that you use your influence in every community with which you come in contact to cause the true facts to be known. The public should demand the proper sanitary protection to which it is entitled.

THE AMES, IOWA, WATER SUPPLY[1]

By P. F. Hopkins[2]

The City of Ames, Iowa, derives its water supply from a thirty foot sand and gravel stratum, lying between the depths of seventy-five and one hundred and five feet below the normal ground surface. The water is organically pure and is satisfactory as a city supply, except that it is somewhat hard—about 16 grains—and carries a high iron content. At the present time the water is aerated, but adequate storage is not available to give detention period sufficient to settle out the iron. Consequently, this settlement takes place in the mains and results in annoying discoloration whenever any unusual disturbance occurs in the mains. Frequent flushing helps, but the relief is only temporary. No treatment other than the aeration is given the water. It is tested on Tuesday and Thursday of each week and is always found satisfactory. Occasionally the Bacteria aerogenes show up, but the irregularity with which this occurs indicates contamination from some source after the water has left the ground. With the iron removed, the water would be entirely satisfactory as a supply, and its accessibility and abundance make the consideration of any other supply unnecessary.

It is not, therefore, the supply itself that is causing the city administration concern, but rather the inadequacy of the wells, storage, and distribution system. The rapid growth of the city in the past few years has necessitated heavy outlay for new mains, hydrants, valves, meters, etc., all of which have been financed from the earnings of the plant, so that the ever increasing discrepancy between the demand and the storage, while not entirely overlooked, was at least neglected. Certain incidents have impressed on those directly in charge of the water supply the absolute and immediate need of strengthening the system, and in April, 1923, a special election was called to vote a $70,000 bond issue to carry out the needed extensions.

This election was peculiar in that it carried by an overwhelming

[1] Presented before the Iowa Section meeting, October 25, 1923.
[2] City Manager of Engineering, Ames, Iowa.

majority and yet failed—the vote being 1405 affirmative and 44 negative. The factor which was responsible for the failure was the statute which requires such bond issues to have an affirmative vote equal to a majority of all votes cast at the last general city election. It so happened that the "Sunday Movie" question had been an issue at the last election and a record vote of 2835 votes had been cast. The ordinary city election would hardly bring out more than 700 to 800 votes. There never was any fear of the negative votes—just a plain question of getting the people sufficiently interested in their dire need to go to the polls. This we were not able to do although every means of publicity was exhausted. It seems as though as long as a man finds water at his tap whenever he wants it, it is almost impossible to shake his childlike faith that somebody, somehow, will always see that he does have water. Tell him the facts and show him what might happen in case of a failure of the supply, and he will say: "Yes, yes, we must do something at once," but on election day he is busy, or he forgot to register, or some other reason or excuse prevents him voting.

Water for the downtown section, embracing the first three wards, is furnished from the city plant located in the eastern part of the city; water for the fourth ward, the section lying south and west of Iowa State College, is purchased from the College and distributed by the city. The College, being in about the same situation as the city as regards its water supply, has asked for several years that the city take over the fourth ward supply, and provision for this was included in the proposed extensions.

Two general methods were considered in connection with the fourth ward water; providing wells, storage, etc., in the fourth ward and operating it as a separate system, or interconnecting the two sytems and supplying all water from the down town plant. This second plan was adopted for the following reasons: (1) connecting the two systems would make the entire supply of the city and college available in emergency for the whole city and the College, (2) the source of the supply being the same for both sections makes the iron removal a necessity, and one plant would be more economical than two, both in first cost and in operation, (3) simplified operation, as the down town plant is operated in conjunction with the municipally owned light plant.

The down town demand varies from 350,000 to 500,000 gallons per day, the greatest demand coming during the summer months;

the fourth ward usuage is fairly constant at from 175,000 to 200,000 gallons per day, the summer demand being offset during the winter months by the presence of large numbers of students who are pretty well concentrated in the fourth ward. The average daily demand, then, for the whole city is at present around 600,000 gallons.

The present down town plant consists of two twelve inch wells, having a combined capacity of about 600 gallons per min., or about 850,000 gallon per day, a 100,000 gallons concrete storage reservoir, a 50,000 gallon elevated steel tank, two centrifugal service pumps having a combined capacity of 1000 gallons per min., and a 1000 gallons per min. steam driven Underwriters fire pump. The well pumps and service pumps are motor driven. It is readily seen that the storage, even for the down town section alone, is ridiculously inadequate, being less than a half day's supply.

The plan proposed for the extension embraces the following: (1) one additional well of 1000 gal. per min. capacity, (2) a concrete reservoir of about 800,000 gallons capacity, preceded by rather elaborate aeration, some chemical feed and a long mixing chamber travel, all intended to hasten the precipitation of the iron, and with provision for following the reservoir with filters as soon as finances would permit, (3) an additional service pump, (4) a booster station located near Squaw Creek and Lincoln Way, and a connecting main to the fourth ward system, (5) a 150,000 gallon elevated steel tank in the fourth ward, (6) considerable additional mains in the fourth ward, required to strengthen that system and cut down friction losses between booster pumps and elevated tank.

The booster station is required because the general elevation of the fourth ward is somewhat higher than the eastern portion of the city, and because some of the four story buildings in the fourth ward are situated on the highest ground. The booster pumps will be in duplicate, motor driven and of 500 gals. per min. each, so arranged that they may be operated in series, giving fire pressure if desired. They will operate automatically, being controlled by the variation in pressure on the discharge side of the pumps. A by-pass line provided with a check valve will insure a constant supply of water to the fourth ward, in case the booster pumps failed, although the pressure would be only that provided by the down town system. A second by-pass line will permit the backing in of the fourth ward reserve and the College supply in case of emergency. In other words, instead of the present 150,000 gallons storage available for the down

town section, there will be 1,100,000 plus the 400,000 gallons College supply, or 1,500,000 gallons, ten times the present storage.

The financial condition of the Department is good, the system having a conservative valuation of $150,000 with a bonded indebtedness of $35,000, and $12,000 cash on hand to take care of main extensions. All extensions are being financed from the plant's earnings. Since Jan. 1, 1921, six miles of mains have been laid, thirty hydrants added, and over 300 new meters installed. Mains are being laid at the rate of about three miles per year, with a mile and a half of pipes on hand to be laid yet this fall. We now have 24 miles of mains, 160 hydrants, and over 1800 services, all metered. It is intended to provide the new well this winter, as the emergency is too great to risk longer delay.

No trouble is anticipated in carrying the bond issue after next spring election, as the prople have had an impressive lesson in what lack of interest can do. No increased levy will be made to finance the bonds. All that is being asked is simply their authorization.

SOME PROBLEMS OF CEDAR RAPIDS WATER WORKS[1]

By H. F. Blomquist[2]

The problems of the Cedar Rapids Water Works are not unlike those that come at intervals to any other water works. The increase in the urban population together with changes in the standards of living have brought about increasing demands both in quantity and quality of the public water supplies in all cities. Water works are generally able to meet the increased demands by piece-meal additions to the supply and equipment for various periods of time, but ultimately, under ordinary conditions, a time comes when further piece-meal additions become uneconomical and impractical, and sometimes impossible.

In a decade the population of Cedar Rapids has increased 38 per cent, and in the same period the water consumption has increased 41 per cent, although during the same period the percentage of metered services was increased to 100 per cent so that there is not very much waste of water. The water consumption per capita is moderate, being approximately 84 gallons per day, which should perhaps be considered a little high since some of the largest manufacturing industries have their own water supply.

Unfortunately, too, the war prevented the making of improvements for meeting the increased demands, and at the end of the war, like many other water works, Cedar Rapids was a long way behind in its program of expansion.

The supply consists of two sources, the Cedar River, and two 10 inch artesian wells, 1450 feet deep. The wells are pumped by electrically driven Hill-Tripp axial impeller pumps, one of which lifts the water about 75 feet to the surface and the the other has a centrifugal pump on same shaft which pumps the well water directly into the pipe system. The Cedar River water is now purified by short sedimentation and sand filtration. A part of the filters are of the old Jewell wooden tub type, installed 26 years ago. There are also

[1] Presented before the Iowa Section meeting, November 3, 1922.
[2] Superintendent, Water Works, Cedar Rapids, Iowa.

two units of concrete construction 10 years old. The wells have a capacity of about two million gallons, and the filters about seven million gallons per day. Until this season no sedimentation space was provided for preparing the water for filtration except a small compartment in the bottom of the tub filters. River water was, therefore, supplied directly to the filters without any preparation except the addition of alum solution into the suction pipe of the pump. This solution was somewhat mixed with the river water by going through the pumps, and coagulation had started when water reached the filter beds. The absence of sedimentation made the operation of the filters extremely difficult, especially during periods of high turbidity in the river water. The large amount of solid matter which collected on the surface of the filters was hard to remove, and washing of filters sometimes resulted in rolling the surface sediment into balls. Our plant gained a reputation of forming mud balls in the sand beds. The direct system of pumping together with limited clear well capacity, coupled with the above condition of the filter plant, created a problem in providing an adequate supply of water during the peak demands.

The consumption of water has exceeded six million gallons per day and, under direct pumping, periodic demands during the evening sprinkling hours during hot weather has been as high as a rate of eleven million gallons per day. In short, the problem confronting our water works when the speaker became connected with it two years ago, was to provide adequate fire protection and a peak demand as high as a rate of eleven million gallons per day with a supply of less than this amount, and subject to considerable decrease by possibility of breakdowns of well pumps and difficult operation of filter plant because of lack of sedimentation facilities.

Since the location of the present plant is such that the nesessary space for expansion, and especially for sedimentation basins, is not available, it was deemed impractical to make any more additions to the present purification plant, or any improvements except those absolutely necessary, and to bring the present equipment to as high efficiency as possible with as little investment as possible, because sooner or later a new location for a purification plant would have to be provided, or a different supply secured. It is possible to get a good flow of artesian water in Cedar Rapids, and the possibility of meeting the increased demand with additional wells has been under consideration. The situation called for the immediate adoption of

some improvement program and a study of the local conditions for reaching conclusions as to the best source of future supply, whether it should be artesian wells or Cedar River, or both. Burns & McDonnell, consulting engineers, of Kansas City were called in to give their recommendation on these questions. A program of improvement was adopted about a year ago which is based on their recommendations, with some changes in details.

The improvements decided upon were divided into two parts: First, making a change from direct pumping to a gravity supply, by constructing a reservoir with a storage capacity of more than the present maximum days demand, also to lay a system of feeder mains to provide satisfactory pressure in all parts of the city. The second part of the program will consist of a new or increased source of supply, but whether this will be Cedar River or artesian water, or both, has not yet been fully decided. The first part, practically completed this year, consists briefly of the following work: The construction of a seven and one-half million gallon reservoir in Beaver Park at an elevation approximately 170 feet above, and two and one-half miles distant from the business section of the city, and a system of feeder mains consisting of a main pipe line, 24 inches in diameter, from the business section direct to the reservoir, and about four miles of secondary feeder laterals.

For this purpose a campaign for a bond issue of $450,000 was started early this year and voted on at the spring election, with the votes approximately two to one in favor of the proposition. Only $400,000 of these bonds will be issued, as this amount will be sufficient to finance the improvement. A contract for the reservoir was let May 26 for approximately $100,000, and the concrete work is now practically completed. The main feeder pipes will be completed in about two weeks and during the first of December we except to put this part of the improvement in service, and thus change from direct pumping to a gravity supply.

This part of the work will give the advantage of a comparatively large storage for fire protection, and of permitting the operation of our wells and purification plant at a uniform rate throughout the twenty-four hours of the day and thereby meet the demands on our system for a few years. In the meantime it is our purpose to prepare for the second development in the improvement plan, that of providing the best possible supply for the future. If river water will be continued, it is the intention to build an up-to-date purification plant and pumping station in a new location.

The adoption of a reservoir gravity system in place of direct pumping precludes the continuation of increased pressures in the system during fires. It is our opinion that, under our conditions of operation, particularly with limited supply and the undesirability of increasing it in piece-meal fashion, it was the proper solution. The variations in demand at different hours of a day in this city have been as high as 400 per cent. Such high variation does not occur often, but it must be met when it does occur. Adequate storage in a gravity supply, therefore, makes it possible for a given supply and pumping equipment to give at least double the service that can be given without such storage, besides giving the added protection of a large amount of water directly available without pumping in case of large fires. These advantages are more desirable than increased pressures under limited capacities from direct pumping, especially in large cities where fire pumpers may easily furnish the increased pressures during fires.

By this change the present supply and pumping equipment will be able to furnish an adequate quantity for a few years, and permit sufficient time for proper investigation and development of a permanent supply for the future. It will also be possible to get better results from the filter plant because it will not be necessary to run filters beyond proper rates for good results.

THE DRY FEED OF CHEMICALS[1]

By L. M. Booth[2]

The use of continuous dry feeders for chemicals in water purification is the result of the successful employment of dry feeding apparatus in the cement, grain, chemical and other industries. The problem before our designers has been to adapt well known and tested equipment to water purification uses.

In some of the larger water filtration plants, for example at St. Louis, where the volume of chemicals to be handled is greater than in most plants, the plan of adding weighed batches of dry chemicals was adopted with the inception of chemical treatment at St. Louis in 1904.

So far as the speaker is aware, credit for the initial development of continuous dry chemical feeders in water purification belongs to Allen Hazen and Robert Spurr Weston, who first used a screw type conveyor feeder in 1907, at Brisbane, Australia.

At this time there are about 400 dry feeders in water purification plants in the United States. This includes large industrial installations as well as filter plants purifying public supplies.

The various commercial feeders now on the market may be divided into the following four classes: Screw conveyor, ribbon conveyor, drum wheel, and table feeds. Most manufacturers arrange for the operation of feeders by means of electric or water motors. In some instances, power is taken from a line shaft. The amount of power required varies from approximately 0.1 to 0.5 horse power, depending upon the size and type of the feeder.

Most feeders are designed for pulverized or small lump material. Some feeders readily handle, without previous screening, cakes of lumpy hydrated lime, soda ash, sulphate of aluminum or sulphate of iron. The handling of large lump material (not ground) is a benefit only when pulverized chemicals are not available, as for example

[1] Presented before the North Carolina Section meeting, November 16, 1922.

[2] President, Booth Chemical Co., Elizabeth, N. J.

where sulphate of aluminum is made at the filtration plant and is merely crushed into large lumps before use. Since the chemical manufacturer's price of pulverized sulphate of aluminum is the same as that of the lump product, the feeding of lump material may be, in instances where the chemicals are purchased, a distinct disadvantage. The reason is that provision must be made for dissolving the lump chemical before it is introduced to the water to be purified.

While all manufacturers of dry feeders for water purification are in a position to supply solution making equipment, a number of them recommend that the feeders be installed so that the dry pulverized materials may be discharged from the feeder directly into the water to be treated. Of course, in many plants, where existing conditions prevent the direct application of the chemicals to the water, it is necessary to convey them from the feeder to the point of application by a stream of water. This, in some instances, is provided by the waste water from the water motor driving the feeder.

The ideal place for the installation of a dry feeder is in the chemical storehouse, if this is within a short distance of the filter plant. As previously noted, the water entering the plant should pass beneath the feeder on its way to the coagulating basin. If this arrangement is provided for, it is possible to install the chemical feeder so as to insure the minimum handling of chemicals. The practice of installing chemical feed apparatus right under the filter operator's nose, as has been determined to be desirable by experience with orifice boxes, need not be followed with dry feeders. These are reliable and the service is not subject to the interruption due to the accumulation of foreign matter in pipe lines, valves, etc., which is the usual experience where solutions are handled.

The prices of standard dry feeders vary from about $300 to $1200. In each case the figures named include the complete feeder, with supply hopper, electric motor, and solution equipment. The range of feed for any given machine is usually such that the maximum feed is ten times the minimum. This is from a few pounds per hour, in the case of the lower priced feeder, up to 1000 pounds per hour for the larger feeders.

Besides the advantage of low first cost, the dry feeder is more economical of space than solution tanks and orifice boxes.

For new plants, the use of dry feeders permits important savings in building construction. The second story, frequently the logical

location for chemical storage when solution tanks are used, is not needed.

All filter plant operators are familiar with the corrosion, stoppage and leakage of coagulant piping. This nuisance can be eliminated absolutely by installing the dry feeder so that the inflowing water receives the dry chemicals.

Besides the advantages of simplicity, low first cost, and ease of control, the dry feeder method is characterized by a certainty of operation not readily obtained by other means.

FINAL REPORT OF THE COMMITTEE ON SANITARY DRINKING FOUNTAINS[1]

The advent of sanitary drinking fountains was the direct result of laws prohibiting the common drinking cup. In 1910 there were few states or municipalities which prohibited the use of the common drinking cup. By 1920 many states recognized the necessity of prohibiting the use of the common cup and laws for its prohibition were enacted. Eight states passed such laws in 1917 and six more in 1910. Manufacturers of sanitary equipment recognized readily the lucrative field for specially designed drinking facilities, and during the period from 1910 to date about twenty large scale manufacturers and numerous small dealers were offering various types of sanitary drinking fountains to the trade. In the early period of the manufacture of such equipment little attention was given to the public health aspect of the apparatus placed upon the market. No special thought was given, at first, to the sanitary efficacy of the equipment, with the result that many types of fountains were put in service, the use of which were as potentially dangerous in the transmission of infectious diseases as was the common drinking cup. Numerous investigations carried on in the past few years have demonstrated clearly that the straight jet fountain, permitting the incoming water to pass through a cup or reservoir that is not drained, and other poorly designed apparatus, may result in the transmission of bacteria from one person to another. In the conclusions reached by the committee of the Iowa Section of this Association, in their report of October 23, 1919, definite recommendations are given for the type of fountain that will eliminate opportunity for contamination. These conclusions are endorsed by your committee and are given herewith, in full, as they cover all the essential features of design of operation required in apparatus of this kind.

[1] This report has been prepared under the direction of Council. The personnel of the Committee is as follows: S. T. Powell, Chairman, Baltimore, Md.; John H. Dunlap, New York; J. H. Dunwoody, Erie, Pa.; Ralph Hilscher, Berkeley, Calif.; and W. M. Mitchell, Gross Ile, Mich.

Conclusions. 1. All types of drinking fountains with vertical jets are to be condemned.

2. Most types of drinking fountains with slanting jets are to be condemned.

3. To be sanitary, drinking fountains should conform to the following specifications:

a. The jets shall be slanting.

b. The orifices of the jets shall be protected in such a manner that they cannot be touched by fingers or lips, or be contaminated by droppings from the mouth, or by splashings from basins beneath the orifices.

c. The guards of the orifices shall be so made that infectious material from the mouth cannot be deposited upon them.

d. All fountains shall be so designed that their proper use is self-evident.

Your Committee has devoted its efforts primarily to reviewing the present status of laws which have been enacted to control the installation of equipment of this type. It has considered also the need for future legislation and control to prevent the use of insanitary drinking fountains. At the close of 1921, there were laws or sanitary regulations in many states specifying the use of sanitary drinking fountains. Few states, however, have adopted specifications for the design of fountains which are efficient or satisfactory. There is a need still for bringing before the public and many of the health authorities the potential danger that exists in the use of sanitary drinking fountains of many types now offered to the trade.

Section 61 of the Railway Sanitary Code of the United States Public Health Service specifies the kind of fountain permissible. These specifications are as follows:

Sec. 61. Drinking Fountains.—If drinking fountains of the bubbling type are provided in any railway station, they shall be so made that the drinking is from a free jet projected at an angle to the vertical and not from a jet that is projected vertically or that flows through a filled cup or bowl.

This portion of the code is a decided step forward in attempting to eliminate the installation in railway stations of fountains of dangerous design. The specifications, in our opinion, are not sufficiently complete, however, in that no mention is made of the guards that should be used, nor is any provision made for protecting the jet from the mouth or fingers of the users.

A review of the trade catalogues of recent date has shown that there is still a great variety of sanitary drinking fountains offered to the public, a large majority of which are of the insanitary type. Many of these apparatuses in no way meet the requirements set forth by

the Committee of the Iowa Section, or of Section 61 of the Railway Code. This condition may not be as discouraging as it appears, however, due to the fact that many of the manufacturers do not revise their catalogues every year. We are of the opinion, however, that there are still a large number of poorly designed drinking fountains manufactured and sold. This condition will exist until the manufacturers realize that only sanitary fountains of good design are in demand.

During the past year a large number of sanitary fountain installations have been inspected. Less than 10 per cent of the number of fountains inspected were of the design that prevent infection being transmitted directly from one person to another, and only 5 per cent might pass Section 61 of the Railway Code. Not one of these installations could meet the requirements specified by the Iowa Section. This appears to be a serious indictment against the enforcement of health regulations, since in every instance where this condition existed there were laws to prohibit just this situation. As a result of these studies the following conclusions and recommendations are given:

CONCLUSIONS

1. Infections may be transmitted from one person to another from sanitary drinking fountains of the bubbling type with undraining reservoir, or fountains that permit the mouth or hands to come in contact with the surface of the jet.
2. Many manufacturers of fountains are not familiar with the sanitary requirements to be met by such apparatus.
3. Laws on the statute books regarding drinking fountains of many states are not enforced.

RECOMMENDATIONS

1. The Association should adopt the specifications for sanitary drinking fountains recommended by the Iowa Section, October 23, 1919.
2. All sanitary drinking fountains installed in public places should be of the standard design as set forth herein, or of such a design as to fulfill the sanitary requirements made necessary by the improved type.
3. Legislative regulations in all states, where these are not now in force, should specify the type of sanitary fountain to be permitted.

4. Copies of this report should be sent to technical papers, having a circulation among manufacturers of drinking fountains, requesting that the report be published in full.

5. Stricter supervision by health authorities of the type of drinking fountains installed in new buildings should be brought about.

DISCUSSION

ON VALUATION[1]

That the art of valuing public ulitity properties for rate making purposes has not been developed to a stage that will permit of the deduction of principles sufficiently definite to constitute an exact science, the three decisions in the Southwestern Bell, the Bluefield Water, and Atlanta Gas cases handed down last year by the Supreme Court of the United States, clearly and unmistakably demonstrate. And who is there that would have valuation made such a positive rule that all the elements which give to each case its individuality would be impossible of consideration, and that Courts and Commissions would be hampered in the application of that calm and deliberate judgment which is essential to the determination of that value which is just and reasonable to the public, to the utilities, and to the security holders alike?

From the Southwestern Bell and Bluefield Water cases in particular, it seems certain that actual consideration of, and substantial weight to, the present greatly increased cost of labor and materials must be given; but that reproduction cost is not *the* measure of value is equally certain and that the terms "reproduction cost" and "present fair value" are not synonymous must be admitted by even the most partisan observer. It is interesting to note that original cost is still a measure of value and may, when it represents property installed at well distributed points over the price curve (as with the Bluefield water properties), become the controlling measure. Accrued depreciation still seems to be a factor that must be reckoned with in considering both the cost to reproduce and the original cost.

The three decisions are undoubtedly a decided contribution to the subject of valuation, but in the final analysis, stripped of their legal phraseology, placed side by side, and viewed through their majority opinions (which become the law), illumined by the forceful language of the minority, what more do they say than that the Court still adheres to the principle enunciated twenty-five years ago

[1] JOURNAL, January, 1924, page 1.

in *Smyth versus Ames?* One Commission was reversed because it had failed to take into consideration the increased cost of labor and materials; another was reversed because the rates set by it did not allow a fair return on even the minimum value which might be placed on the property; and a third was upheld after it had given consideration to the increased cost of reproduction *less depreciation* and to all the other elements of value and had finally adopted as rate base a figure which very nearly represented the original cost.

The Southwestern Bell case touches a point which, to my mind, is most significant. In this connection the Court says, "An honest and intelligent forecast of probable future values, made upon a view of all the relevant circumstances, is essential." Evidently the Court had in mind the establishment of the very "stable" rate base for which Mr. Justice Brandeis contended when he declared, in his minority opinion, "The adoption of the amount prudently invested as the rate base and the amount of the capital charge as the measure of the rate of return would give definiteness to these two factors involved in rate controversies which are now shifting and treacherous, and which render the proceedings peculiarly burdensome and largely futile. Such measures offer a basis for decision which is certain and stable. The rate base would be ascertained as a fact, not determined as a matter of opionion. . . . . It would not be distorted by the fickle and varying judgments of appraisers, commissions, or courts." He probably had in mind some of the "expert" testimony which is to be expected in every rate case and from which Commissions and Courts are supposed to decide whether a property can grow up over night ready to perform all the functions of the existing plant and if so whether the effect of its hasty erection, coupled with its long drawn out appraisal, should cause it to be burdened with an "overhead" cost several times the cost of its physical elements, or whether on the other hand the property has been rapidly deteriorating from the time of its very inception in the promoter's mind, until today its value has been reduced to an infinitesimal part of the original. If there is one thing for which Mr. Justice Brandeis did argue, both in his two minority opinions and in his majority opinion, it was that the findings of Commissions as to values are to be accorded great weight, but that this very fact makes it incumbent upon the value-determining body to keep its feet on the ground and deal fairly with utilities and public alike in order to attract, by a conservative degree of certainty of return, that capital the flow of which into its properties is the very life blood of public utilities.

A reading of these three decisions leads one to the conclusion that too much emphasis is being placed on the valuation process and results and that insufficient weight is being given to the many other factors involved. The rate of return should be more strongly stressed. When Commissions have gotten to the point of granting increases for skillful and economical operation and permit utilities to share in the fruits of good management, and on the other hand when public service companies content themselves with a reasonable rate of return on something less than the highest valuation which they can possibly claim, much of the agitation over valuation will cease and the rate making process will become more of a rational adjustment of the economic features presented in each particular case. Certainly a low rate of return and a low valuation is no fairer than a high rate of return and a high valuation unless the interests of the public and the utility alike are served by this combination.

The fact that the Supreme Court set its stamp of approval on the 4½ per cent gross earnings charge levied on its subsidiaries by the American Telephone and Telegraph Company is, to my mind, the outstanding feature of the Southwestern Bell case. The fact that the valuation of franchises to do business and the inclusion of so-called losses from operations during recent years were excluded from the Atlanta gas case are of deeper moment than the question of valuation. That a 6 per cent return is too small and that, "A return of 7.25 per cent—in addition to this tax exemption—can not be deemed confiscatory" goes far toward clarifying one important element ever present in rate cases. Likewise the treatment of the federal corporate income tax as an operating charge will dispell many doubts on this question.

H. CARL WOLF.[2]

[2]Chief Engineer, Public Service Commission, State of Maryland.

SOCIETY AFFAIRS

EXECUTIVE COMMITTEE MEETING

The Executive Committee of the Association held a special meeting in New York City on January 18, 1924 at the call of President George W. Fuller. The following resolutions and motions were passed.

WHEREAS, For many years John M. Diven, Past-President of the American Water Works Association, has served as its Secretary, with unflagging interest in its welfare and at a sacrifice of time and effort rarely made by the officers of societies of this character; and

WHEREAS, In taking charge of the water works of Troy, N. Y., Mr. Diven has felt it desirable to be relieved of the detail work which the Constitution imposes upon the Secretary;

Therefore Be It Resolved, by the Executive Committee of the Association, assembled at a Special Meeting in New York on January 18, 1924, that the resignation of Mr. Diven as Secretary be accepted with the appreciation by the Executive Committee of his past services as the Secretary, as expressed herein, and that the President be and hereby is requested to present the name of Mr. Diven for Honorary Membership at the next annual convention of the Association.

And Be It Further Resolved that the Executive Committee recommend that the position of Secretary Emeritus be established by amendment of the Constitution and that, pending action on the establishment of this position, the Executive Committee employ Mr. John M. Diven at the salary of Fifteen Hundred ($1500) Dollars per annum with the office title of Secretary Emeritus, his duties to be developing the interests of superintendents in the work of the Association, assisting in the increase in membership of the Association and advertisers in the JOURNAL, assisting in the preparation of the program for the convention with special reference to the superintendents, and attending the convention and assisting in the conduct thereof.

It is regularly moved and carried that a Committee consisting of the President, Mr. Fuller, the incoming President, Mr. Jordan and Messrs. Bartow, Cramer, Batchelder, Andrews and Brush be appointed to make recommendations as to the filling of the Secretary's office, location of the headquarters of the Association and other questions pertinent thereto.

It is regularly moved and carried that the Membership of the Association be advised through publication in the March JOURNAL of the resignation of Mr. John M. Diven as Secretary, and that Mr. W. M. Niesley, the present office assistant, will temporarily carry on the duties of the Secretary's office under the direction of the President pending the selection of a Secretary.

Special Notice

The Secretary's office has been transferred to Rooms 1012-13, 170 Broadway, New York.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Revolving Screens for Low-lift Pumping Station, Detroit, Filters. T. A. Leisen. Eng. News-Record, 91: 14, 1923. Seven sets of screens, each operated by 5 H.P. motor and at speed of 10 ft. per min., are installed in Detroit water purification plant, at point before water reaches pumps. Each screen is made up of 38 panels 24" × 72". Function of screens is to intercept all floating or slush ice coming through tunnel and incidentally, to prevent passage of fish and floating debris. Opening in screens is ½" square.—*Frank Bachmann.* *(Courtesy Chem. Absts.)*

Coal Storage for Year's Supply for Detroit Water-Works. Anon. Eng. News-Record, 91:10–11, 1923. Duplicate coal handling equipment, boiler houses, and coal sheds, with storage capacity of 25,000 tons, give continuity of service. Coal is brought in by barges, dumped into hopper with reciprocating feeder, and crushed by 30" double-roll crusher fitted with replaceable steel teeth. Crushed coal is conveyed to storage house by 24" belt conveyor. —*Frank Bachmann.*

Successful Means of Removing Hard Spots from Filter Beds. W. C. Wills. Eng. News-Record, 91: 232–3, 1923. Underdrains consisted of 1¼ inch C.I. laterals on 6-inch centers, drilled every 6 inches with 2 holes, ¼ inch diameter. Inspection showed that the gravel had cemented above laterals, stopping flow of wash water. Tailings in varying sizes, from 2 x 4 x ½ to 5 x 6 x 2 inches, substituted for gravel over laterals, removed difficulties.—*Frank Bachmann.* *(Courtesy Chem. Absts.)*

Waltham, Mass., Reservoir Waterproofed by a New Lining. M. W. Fisher. Eng. News-Record, 91: 185, 1923. Disintegration of reinforced concrete, due to seepage and frost action, made more waterproofing necessary. Waterproofing consisted of mop coat of Texaco No. 56 waterproofing asphalt, applied hot to inside wall. Waterproofing felt was then applied with another coat of Texaco No. 56. This operation was repeated 5 times, outside layer, however, being a 6 oz. saturated duck fabric. Following this, 4 inch brick facing was constructed from floor to top of wall.—*Frank Bachmann.*

How Oklahoma City Water-Works Dam Withstood Floods. A. S. Holway. Eng. News-Record, 91: 292–4, 1923. Previous records were broken by June floods. Practically all bridges on North Canadian River were washed out. Flood threatened waterworks storage reservoir of Oklahoma City as twice the capacity of spillway passed over dam. By using sand bags by thousands, dam was saved.—*Frank Bachmann.*

Aluminum Hydroxide Solution. Joseph W. Coxe, Jr. Chem. and Met. Eng., 29: 279, August 13, 1923. New coagulating agent, suitable for water purification, described. Addition of concentrated solution of soda ash to concentrated solution of aluminum sulfate, in proportion of one part of soda ash to 4 parts of alum, forms no precipitate. Diluting causes coagulation. No alkalinity is required in water to be coagulated. Free CO_2 is liberated in the concentrated solution; most of it passes off as gas. Author claims that amount of aluminum sulfate necessary for clarification is not increased by this treatment.—*John R. Baylis.*

Wrestling with Water Waste in Chicago—Only 10 Per Cent Metered. L. R. Howson. Fire & Water Eng., 73: 727, April, 25 1923. Chicago water works at present time has 7 cribs: 60 miles of tunnels, from 5 to 14 ft. in diameter, with nominal capacity of over 1,400 million gals. per day. There are 10 major pump stations, with normal capacity of 1,150 million gals. per day, and average daily pumpage of nearly 800 million gals. It serves population of nearly 3 million poeple, in area of approximately 200 sq. miles, through c.-i. mains, from 4 to 48-in. diameter with aggregate length of nearly 3000 miles. It supplies approximately 325,000 premises, of which less than 10 per cent are metered; remainder being on frontage assessment basis. In 1921, the metered 9½ per cent of the services used 25 per cent of water pumped, and paid, at average rate of 6½ cents per 1000 gals., for all water used. Remainder of supply, unmetered, yielded revenue of but 1.6 cents per 1000 gals., or, materially less than cost of supplying it. Average pressure at present is approximately 20 lbs.; nearly three-quarters of city is suffering from insufficient pressure for fixtures on third floor to be used at all times. This is due to friction loss resulting from passage of excessive amount of water through mains. It is believed that 125 gals. per capita per day represents use and unavoidable loss of water. Gross pumpage in 1921 averaged 267 gals. per capita per day, leaving preventable waste at 151 gals. per capita per day, or approximately 56 per cent of total pumpage. Amount of preventable waste, approximately 425 million gals. at present time, is more than combined gross pumpage of Cleveland, Milwaukee, Cincinnati, Newark, New Orleans, Providence, Atlanta, Boston, and Columbus, serving over 3 million people. If present waste continues, daily consumption in 1950 will be approximately 2,000,000,000 gals. If meters are placed on all new services, and careful leakage survey inaugurated, it is believed that daily consumption can be reduced not to exceed approximately 1,400,000,000 gals. in 1950; if meters are placed on all services in next 10 years it is believed consumption can be reduced to 600,000,000 gals. per day in 1950. It is estimated that expenditure of 88 million dollars on plant additions in next 30 years can be saved, if universal metering put into effect within next

10 years; savings in operation are estimated at 145 million dollars. Nine examples are given to show what metering has accomplished in other cities. Article is well illustrated by diagrams. (*Cf.* this J., **10:** 1135).—*Geo. C. Bunker.*

Gravel Versus Rock as a Source of Well Water. John W. Toyne. Fire & Water Eng., **73:** 827, May 9, 1923. Summary of studies of water supply in connection with new pump station for South Bend, Ind., having ultimate capacity of 25,000,000 gallons per day; and short notes concerning wells drilled at other places. Care must be taken not to select a strainer with combination of metals that will set up electro-chemical action and render well useless within a few years. After strainer set, finer particles in strata must be worked through it, and removed from well; air is most effective agent for this. Author's experience and observations lead him to question desirability of water supply in rock, if one is available in suitable gravel strata under favorable topographic conditions.—*Geo. C. Bunker.*

Water Purification Problems—How They Should be Handled. F. A. Dallyn and A. V. De Laporte. Fire & Water Eng., **73:** 819, May 9, 1923. Sources of supply for municipal water works in Ontario are, with few exceptions, "clear waters." Problems of filtration are the removal, respectively, of (1) bacteria derived from sewage contamination; (2) occasional turbidity; (3) color and organic matter; and, for a few supplies, (4) considerable quantities of turbidity. Economically, problem is removal of color in northern parts of Province; and removal of iron and occasional turbidity in Trent and Rideau Valleys. Where water receives 2½ grains per gal. of alum, cost of alum alone will be from two to three times actual amortisation burden of the plant. Trend of practice is toward decreasing bacterial efficiencies in rapid sand filtration, and supplementing filtration by chlorination. Fortunately this trend of practice, is not, under present conditions, attended by serious health hazards, because last 10 years have witnessed immense declines in incidence of typhoid fever, so that water supplies do not to-day represent potential danger they did in last decade. In Province of Ontario much emphasis placed upon location of points of intake for supply. Very few plants, furnishing domestic water supplies, have intakes subject to such gross pollution, as prevails in many American cities. Density of population in U. S. calls for size of plant rather larger than is the rule in Ontario. Use of sedimentation basins with minimum of two hours storage is very advantageous for all colored waters and for iron-bearing waters. Pressure type of filter, without coagulation basins, is adequate, provided theoretical quantities of alum applied, to take care of occasional turbidity; but difficulty of controlling alum dosage requisite for rapid precipitation is so great, that this type is not advocated for waters which may be classed as resistant to treatment. Experimental evidence indicates that for soft, colored, waters optimum condition for coagulation is when H-ion concentration of water has been adjusted through use of alum to pH value of 5.5; for harder waters, and for Great Lake Basin, optimum condition exists when pH value adjusted to neighborhood of 6.5 (*cf.* this J., **10:** 1138).—*Geo. C. Bunker.*

Analysis and Physical-Chemical Examination of the Thermal Carbonated-Sulfuretted-Borated Water of Saturnia. R. NASINI AND C. PORLEZZA. Gazz. Chim. Ital., **52**: 1, 115–24, 1922. From Chem. Abst., **16**: 1834, June 10, 1922. Report of detailed examination of water of this old spring which is a bright colloidal solution of sulfur. Temperature is 37.5°C.—*R. E. Thompson.*

The Manufacture of Fused Cement. E. CANDLOT. Chimie et Industrie, **7**: 456–7, 1922. From Chem. Abst., **16**: 1845, June 10, 1922. Fused cement consists essentially of calcium aluminates. Of the four known compounds ($5Al_2O_3.CaO$; $Al_2O_3.CaO$; $3Al_2O_3.5CaO$; $Al_2O_3 . 3CaO$) the first three yield, on clinkering, hydraulic products which set slowly and harden rapidly. Most valuable characteristics are, resistance to sulfate-bearing waters; slow setting; and rapid hardening (strength at end of three days is equal to that of good grade artificial cement after 28 days).—*R. E. Thompson.*

Influence of Drying on the Resistance of Cement Blocks. F. ANSTETT. Rev. Mat. Constr. Trav. Pub., **148**: 1–2, 1922. From Chem. Abst., **16**: 1846, June 10, 1922. Cement briquettes were completely immersed in water for different periods and tensile strength tests made on some immediately after removal, and on others, at periods of 7, 20, and 26 hours after removal. In all cases strength of body was greatest immediately after removal, and decreased markedly as period from time of removal increased.—*R. E. Thompson.*

Electrical Charges of Colloidal Particles and Anomalous Osmosis. JACQUES LOEB. Jour. Gen. Physiol., **4**: 463–86, 1922. From Chem. Abst., **16**: 1786, June 10, 1922. Interesting discussion of transport of water across collodion-gelatin membranes separating salt solutions and water. Cf. C. A., **14**: 1246, 2285, 2286, 2573; **15**: 2455; **16**: 726, 1597.—*R. E. Thompson.*

Determination of Organic Matter in Water. REINALDO VANOSSI. Analles. Soc. Quim. Argentina, **9**: 276–91, 1921. From Chem. Abst., **16**: 1825, June 10, 1922. Amount of potassium permanganate consumed in presence of sulfuric acid, potassium hydroxide, and sodium bicarbonate, by samples of water containing various amounts of organic wastes was determined. Results were so widely divergent that no definite conclusions could be drawn.—*R. E. Thompson.*

The Removal of Mineral Plant Food by Natural Drainage Waters. J. S. MCHARGUE AND A. M. PETER. Kentucky Agr. Expt. Sta. Research Bull., 237, 1921. From Chem. Abst., **16**: 1827, June 10, 1922. Analyses are given of samples of water from streams and springs in Ky. and from a few places in other states, including data for some of largest rivers in United States. Greatest amount of nitrate nitrogen found in water containing large amounts of phosphorus, indicating parallelism between soluble phosphorus and nitrate nitrogen. High phosphorus content of soils accelerates activity of nitrifying organisms.—*R. E. Thompson.*

Results Achieved by the Corrosion Committee, British Institute of Metals. E. E. Theim. Chem. Met. Eng., **26**: 301-6, 1922. From Chem. Abst., **16**: 1735, June 10, 1922. Failure of brass condenser tubes in marine service is caused by lodgment of solids, harmless in themselves, which trap corrosive substances formed during inevitable process of slow general thinning. Mechanism of this form of corrosion explained.—*R. E. Thompson.*

Influence of Physical and Chemical Treatments on the Adsorptive Capacity of Fullers Earth. G. H. A. Clowes and G. B. Walden. Proc. Am. Soc. Biol. Chem.; Jour. Bio.-Chem., **46**: 18-9, 1921. From Chem. Abst., **16**: 1784, 1922. Adsorptive capactiy for alkaloids appears to be direct function of amount of iron and aluminum contained in Lloyd's reagent and to be adversely affected by silica. Water loss on evaporation has similar effect.—*R. E. Thompson.*

How Should the Watershed be Protected from Pollution: Geo. C. Hodges. Fire & Water Eng., **73**: 681, April 18, 1923. General remarks about improving sanitary conditions on watersheds of the supply of Utica, N. Y. The Kentucky sanitary privy was adopted and has given perfect satisfaction.—*Geo. C. Bunker.*

Political Versus Non-Political Management. R. E. McDonnell. Fire & Water Eng., **73**: 719, April 25, 1923. Protest against management of municipal water works by political boards.—*Geo. C. Bunker.*

Composition of Foams. J. Chatelan. J. Chim. Phys., **20**: 123-131, 1923: Chem. & Ind., **42**: 739 A, August 10, 1923. Gibbs' law connecting surface concentration of a dissolved substance with effect of substance on surface tension of solvent, cannot be confirmed by study of composition of foam produced with aid of saponin, or other colloids. Colloid present in foam takes with it quantities of electrolytes far in excess of amount required by Gibbs' law. In studying foams produced by discharge of effluents into streams, methods based on laws governing adsorption must be used; the important factors being nature, quantity, and dimensions of micelles, acting as carriers of electrolytes, that accumulate in foam. It is necessary also to take into account evaporation, which may further increase concentration of foam. (J. F. S.)—*A. M. Buswell.*

28th Annual Report, Superior Board of Health, Quebec. (1921-2). 412 pp. Improvement effected in river water supplies in a score of municipalities has reduced typhoid death rate in Province from 26.0 to 18.0 per 100,000. This might be lowered to 10, if raw river waters, supplying population of 200,000, were improved. Further research was carried out along two particular lines of investigation: (1) Detection and differentiation of organisms of colon-aerogenes group; (2) Application of H-ion concentration to purification plant control. These studies are still in progress.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Typhoid Fever in New York City. Weekly Bulletin, N. Y. City Dept. of Health, 12: 154–5, 1923. During first quarter of 1923, 115 cases reported, increase of 67 over corresponding quarter, 1922. Part of increase due to outbreak in Borough of Queens. Probable mode of infection, as ascertained in 35 per cent of cases: 11, contact with active cases; 9, acquired out-of-town; and 20, by ice cream, apparently contaminated by carrier.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

How Sanitation Aids Public Health. Richard P. Walsh. Monthly Bulletin, N. Y. City Dept. of Health, 13: 31–8, 1923. Review of activities of sanitarian, and of progress in fields of air conditioning, sanitary plumbing, sewage disposal, industrial hygiene, ventilation, refuse disposal, rodent and vermin extermination, water purification, etc.—*R. E. Thompson.* (*Courtesy. Chem. Abst.*)

How Sanitation Aids Public Health. Alonzo Blauvelt. Monthly Bulletin, N. Y. City Dept. of Health, 13: 25–30, 1923. General discussion. Methods employed by New York City Dept. of Health in enforcing regulations governing sewage and garbage disposal, water supply, swimming pools, bathing establishments, etc., are outlined.—*R. E. Thompson.* (*Courtesy Chem. Absts.*)

Standby Units for Pumping with Comparison of Operating Costs. E. M. Proctor. Contract Record, 37: 467–9, 1923. While Diesel and semi-Diesel equipment are most economical as regards operating costs, a gasolene-engine driven unit could be operated for 30 days before combined operating and capital costs would equal that of steam-, or Diesel-, engine driven.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Safe Water Supplies for Rural Saskatchewan. R. H. Murray. Sanitation Bulletin 2, 1923, Dept. of Public Health, Saskatchewan, Canada. 28 pp. Methods of constructing, protecting from pollution, disinfecting, and selecting sites for wells described. Survey of Province has indicated that commonest cause of well pollution is lack of care in selecting suitable site. The average well water in Province contains approximately 100 grains per gallon of mineral salts, with $CaSO_4$ predominating, and remainder consisting of $MgSO_4$, Na_2SO_4, $CaCO_3$, Na_2CO_3, and NaCl in amounts decreasing in order given. Na_2SO_4 is sometimes present to extent of 4–5000 grains per gallon. All surface water supplies of Province are dangerous. Where ice is cut in winter for use as water supply during year, there should always be at least 2 feet of water under ice when cut, and surface of ice should be scraped free of snow, soft ice, and foreign matter, before storing. As added precaution, water thereform, should be treated with chloride of lime, or boiled. In some sections, rain water is only source of supply. Plant consisting of raw water tank, sand filter, and filtered water storage tank, based on annual rainfall of 12 inches on roof area of 3000 sq. ft., is described and illustrated.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Work of the Bureau of Laboratories During 1922. WM. H. PARK. Monthly Bulletin, N. Y. City Dept. of Health, 13: 73–88, 1923. Work of Bureau reviewed. A.P.H.A. standard methods used for all routine tests on water and milk. Drinking waters containing B. coli in quantities less than 10 cc., or with total bacterial count much in excess of 100 per cc., are listed as suspicious or polluted; but repeated tests and careful consideration of local conditions necessary, in order to judge quality of a source of supply. Standards for bathing pools using well, spring, or city water, permit presence of not more than 10 B. coli per cc. If river or harbor water used, it must not contain more than 30 B. coli per cc. Method of examination of shellfish consists of 5 parallel tests of pooled liquor of 5, or more, oysters. Liquor must contain less than 50 B. coli per cc. Operation of oyster purification plant at Inwood, Long Island, has resulted in considerable reduction in B. coli present in oyster liquor.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Effect of Composition of Brass on Corrosion. PHILIP DAVIDSON. Chem. Met. Eng., 26: 773, 1922. From Chem. Abst., 16: 1927, June 20, 1922.—*R. E. Thompson.*

Electrolytic Concentration Cells as Accelerators of Corrosion. P. D. MERICA. Chem. Met. Eng., 26: 773, 1922. From Chem. Abst., 16: 1927, June 20, 1922. —*R. E. Thompson.*

Causes of Corrosion in Brass. A. S. CUSHMAN. Chem. Met. Eng., 26: 773, 1922. From Chem. Abst., 16: 1927–8, June 20, 1922.—*R. E. Thompson.*

The Treatment of Industrial Waste Waters. ANDRÉ BELTZER. Industrie chimique, 9: 95–100, 1922. From Chem. Abst., 16: 2000, June 20, 1923. General description of treatment of industrial waste waters, particularly those from sulfite and paper mills.—*R. E. Thompson.*

Hysteresis Phenomena and So-Called Mechanical Coagulation of Sols with Rod-Shaped Ultramicrons. G. WIEGNER, J. MAGASANIK AND H. GESSNER. Kolloid-Z., 30: 145–65, 1922. From Chem. Abst., 16: 1892, June 20, 1922. Degree of dispersion was determined by ultrafiltration, by ultramicroscope, and by colorimetric measurements, and was found to change in course of time. The more concentrated the sol the more rapid was growth of particles. "Mechanical" coagulation was produced by filter paper, kaolin, carbon, wood fiber, silk threads, silicic acid gel and gelatin.—*R. E. Thompson.*

The Determination of Bromide in Brines and Mineral Waters. C. C. MELOCHE AND H. H. WILLARD. J. Ind. Eng. Chem., 14: 422–5, 1922. From Chem. Abst., 16: 1919, June 20, 1922. Bromine, obtained by oxidation of bromide, is absorbed in sodium hydroxide solution, and the sodium bromate is reduced to bromide by hydrazine sulfate. After precipitation as silver bromide, weighed bromide is converted into silver chloride by ignition in chlorine; from weight of silver chloride, correction is made for small quantity of chlorine liberated with bromine by original oxidation.—*R. E. Thompson.*

Methods of Purifying Public Water Supplies. NORMAN J. HOWARD. Canadian Engineer, 44, 231-6, Feb. 13, 1923. Excellent review and discussion of modern methods of water purification. Slow sand, mechanical, pressure, Puech Chabal, and drifting sand systems of filtration are described, and relation of pH to filter efficiencies is discussed. Sterilization with chlorine, ozone, and ultra-violet rays; iron removal; copper sulfate treatment; and sedimentation and storage are also dealt with.—*R. E. Thompson.*

The Velocity of the Extension of Thin Layers of Oil on a Water Surface. PAUL WOOG. Compt. rend., **174**: 162-5, 1922; cf. Langmuir, C. A., **11**: 2849. From Chem. Abst., **16**: 1891-2, June 20, 1922.—*R. E. Thompson.*

The Transition from Crystalloid to Colloid Properties within Homologous Series. E. J. WITZEMANN. J. Phys. Chem., **26**: 201-16, 1922. From Chem. Abst., **16**: 1892. June 20, 1922. Biocolloids are regarded as consisting of a concentrated solution suspended in a dilute one and it is pointed out that there is an unequal distribution of energy between the two phases. Two types of this energy differentiation are represented in electric charge on particles and in surface tension at interfaces.—*R. E. Thompson.*

Precipitation Equilibrium. ROBERT GRIESSBACH. Z. Physik. Chem., **97**: 22-94, 1921. From Chem. Abst., **16**: 1900, June 20, 1922.—*R. E. Thompson.*

Modern Method of Water Purification. J. P. O'CALLAGHAN. Shipping, Engineering and Machinery Exhibition, Olympia, Eng. Sept. 7, 1923. Water softening by lime-soda (hot and cold processes) and permutit methods is described. The introduction of a new material, "permutit B," has eliminated necessity of second softening apparatus for use during regeneration in case of latter method. Actual base exchange is somewhat less than ordinary permutit, but its action, during both softening and regenerating, is more rapid, permitting use of higher rates of flow and much shorter periods of regeneration—1 hour, as compared with 12 hours for permutit. The material is also of hardier physical character and therefore less susceptible to loss through wear.—*R. E. Thompson.*

The Relation between Flocculation, Adsorption, and the Charge on a Particle with Especial Regard to the Hydroxyl Ion. S. E. MATTSON. Kolloidchem.-Beihefte, **14**: 227-313, 1922. From Chem. Abst., **16**: 2003-4, June 20, 1922. Results are given of extensive investigation on effect of ions on flocculation of colloidal substances found in soils, and on stability of aggregate formed. Hydroxides and oxides of iron and aluminum are negatively charged in aqueous suspension. Only by absorption of ions, originating in the formation (by preparation according to Graham) of some oxychloride ions, may they be positively charged.—*R. E. Thompson.*

Keeping Qualities of Solutions Containing Chlorine. K. A. GANDHI. Indian Med. Gaz., **57**: 78-9, 1922; Pub. Health Eng. Absts., May 13, 1922. From Chem. Abst., **16**: 2007, June 20, 1922.—*R. E. Thompson.*

Unbreakable Glass? ANON. Fachgenosse, 38: 39–40, 1922. From Chem. Abst. 16: 2015, June 20, 1922. New glass, Silex, is composed of 98 per cent quartz. Coefficient of expansion is so low that beakers and flasks with 1-mm. walls withstand abrupt changes of 400 deg. Glass is also resistant to severe shock tests, although not unbreakable. Color is smoky yellow.—*R. E. Thompson.*

Painting Cement Construction. HENRY A. GARDNER. Paint Mfrs. Assoc. of U. S., Circ. 147: 180–5, 1922. From Chem. Abst., 16: 2033. June 20, 1922. Suggested specification for treatment of cement surfaces: (1) New cement should be washed with zinc sulfate solution and allowed to dry at least 24 hours before applying paint; (2) For exterior surfaces, any high grade paint may be used; (3) For interior surfaces, lithopone paints give good results; (4) Cement floors may be hardened by washing with magnesium fluosilicate, sodium silicate, etc.; then painted with specially prepared cement floor paints. Cold water paints should never be used where humid conditions prevail.—*R. E. Thompson.*

The Aeration of Quiescent Columns of Distilled and of Salt Water. W. E. ADENEY, A. G. G. LEONARD, AND A. RICHARDSON. Phil. Mag. May, 1923, pp. 835–45; Water and Water Eng., 25: 295, 265, July 20, 1923. Aeration is effected in still water by mixing of exposed layer with lower layers to depth of 10 feet; due to downward streaming. Mixing is accelerated by rise in temp. and is more rapid in salt, than in distilled, water.—*Jack J. Hinman, Jr. (Courtesy Chem. Abst.)*

Purification of Boiler Water. F. H. RHODES. Sibley Journal of Engineering, April, 1923, pp. 73–76; through Water and Water Eng. 25: 295, 265, July 20, 1923. A general paper.—*Jack J. Hinman. (Courtesy Chem. Abst.)*

Common Drinking Cup. I. W. C. Pub. Health News, N. J., 8: 8, 538, July, 1923. Note on case of typhoid developed in child who used common drinking cup immediately after thirsty golfer who was himself developing typhoid fever.—*Jack J. Hinman, Jr.*

Typhoid Fever at Rockaway, New Jersey. ANON., Public Health News, N. J., 8: 7, 461 (1923). Epidemic of 41 cases and 4 deaths, due to cross connection from city supply to polluted private industrial supply which received drainage from septic tanks. Typhoid carrier of 4 years' standing was using toilet discharging into one of septic tanks. Flap of check valve between supplies was so encrusted that it could be moved only with a bar.—*Jack J. Hinman, Jr.*

Camp Sanitation Appliances. ANON. Public Health News, New Jersey, 8: 7, 462, June, 1923. A general paper. Recommends boiling in preference to $Ca(OCl)_2$ treatment as more likely to be carried out properly, to safeguard water supply.—*Jack J. Hinman, Jr. (Courtesy Chem. Abst.)*

Hygienic Construction of Wells. Beninde. Volkswohlfahrt, **20**: 48, Jan. 15, 1923; Bull. mens. office internat. d'hyg. publ., **15**: 6, 857, June, 1923. Courses for constructors of wells were instituted in 1914 at Prussian Institute for Water Hygiene, and re-opened in 1922. Certificates are conferred.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

The Water Supply of the Province of Quebec. Ed. Imbeaux. La technique sanitaire et municipale, **17**: 9, 224, Sept., 1922; Bull. mens. office internat. d'hyg. publ., **15**: 6, 857, June, 1923. A general description.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

The Responsibility of Health Officers in Protecting the Public Water Supply. Jack J. Hinman, Jr. Journal of State Medical Society (Iowa); August, 1923. Work of State Water Laboratory assisting district health officers in control of public water supplies is described. Wells over 100 feet in depth must be examined every 6 months; less than 100 feet, every 3 months. Purification plants in Iowa State report at weekly intervals, giving amount of chlorin used and operating figures.—*N. J. Howard.*

Metropolitan Water Board. London, England. 17th Annual Report, 1923. Sir A. C. Houston. Report is most comprehensive in character and covers wide range of routine and research work. During year, some 12,994 samples were examined. Sources of London's water supply described; 80 per cent being derived from river sources and 20 per cent from deep wells. Water is distributed over total area of 537 square miles, supplying 7 million people: averaging about 36 imperial gallons per capita. River water is either stored or chlorinated prior to filtration. Part of well supply is chlorinated, due to slight pollution. Treatment includes super-chlorination with subsequent dechlorination using SO_2. By chlorinating raw river water instead of storing it, a water of better bacteriological quality was obtained, and actual saving in pumpage costs, etc., of $174,529 effected in period covering two years. Storage of water was found to have appreciable softening effect. When chlorine being used, taste troubles were occasionally experienced in New River supply; were overcome by permanganate treatment. No trouble experienced when treating Thames water, to which 0.5 p.p.m. of chlorine was applied. Experimental work of considerable interest on rapid sand filters is described, together with Sir A. C. Houston's views on relative merits of slow and rapid sand filtration. Report is classified under following headings:—resistance to filtration experiments; chlorination of river water; chlorination of well water; prefiltration waters; rapid filters; gulls and fish as sources of B. Coli contamination in water; bacteriophages; meteorological notes; growths in water on top of filters; comparisons between 1921–22 results and 1906–16 averages, description of diagrams and photographs; and general chemical and bacteriological tables. The work on bacteriophages (variously described as bacteriolysant, bacteriolytic enzyme, etc.) presents entirely new line in research. Bacteriophages are described as "being mysterious substances of recent discovery, which have the amazing power even in high dilutions of killing and dissolving certain bacteria." This special research work was undertaken in an endeavour to differ-

entiate B. coli of human origin and those derived from birds, fishes, and lower animals. Author suggests possibility of stored or filtered water containing bacteriophages which might have a lytic action on bacteria which might subsequently develop. "The results, although extremely interesting, as illustrating the behavior of bacteriophages towards intestinal bacteria, failed to establish the points of differentiation." Elaborate tables showing chemical and bacteriological quality of the various river and well supplies; diagrams; and large number of photographs of plankton growths are included. Report will be found of great value and interest to all concerned in purification of water.—*N. J. Howard.*

Reducing Ice Pressure with Compressed Air. Robt. G. Skirrett. Can. Eng., 45: 5, July, 1923. Compressed air system superior to steam jets for prevention of ice jams, and more economical to instal and operate. Ice exerts pressure in three ways all of which have to be considered. Water in freezing increases 8.4 per cent.—*N. J. Howard.*

Reservoir Site near Vancouver, B. C. Can. Eng., 45: July, 1923. Investigations have revealed hitherto unrecognized reservoir site in valley of Capilano river, five miles above waterworks intake of City of Vancouver. Dam 70 feet high would create reservoir about 3 miles long and 2000 to 3000 feet wide, having storage capacity of 6½ billion gallons.—*N. J. Howard.*

Water Storage and Distribution Control. E. Bruce Hall. Can. Eng., 45: 11, Sept. 1923. Illustrated article discusses mechanical contrivances and gives description of valves, sluices, weirs and dams employed on various important water supply projects in British Empire.—*N. J. Howard.*

Rich Mix Strengthens Concrete. From Concrete Data. Can. Eng., 45: 11, Sept., 1923. Controlling factor in strength of concrete is ratio between volumes of mix, water, and cement. Ordinarily concrete mixes contain 3 to 8 sacks cement per cubic yard. Each additional sack of cement per cubic yard will add 500 lbs per square inch to strength of concrete. Richer the mix, also, the more impermeable the concrete. Porous concrete may be injured by frost, allow leakage, or permit moisture to reach reinforcing steel and cause corrosion, with consequent spalling and damage. Impermeable concrete will be free from such troubles. Increased amount of cement does not alter cost of forms, nor labor of mixing or placing. It slightly reduces necessary quantity of aggregate. Extra cost is the additional cement, which is only fraction of total cost. Doubling quantity of cement increases cost only 5 to 15 per cent, while it doubles strength and durability. In structural concrete increased strength may permit use of higher stresses.—*N. J. Howard.*

Effect of Silt on Water Velocity. A. B. Buckley. Abstract of paper presented Inst. of Civil Eng. Can. Eng., 45: 14, Oct., 1923. Velocity of water varies with variations in silt content. Reduction of 14 per cent in velocity of Nile River, Egypt, was observed with increased silt content; difference in hydraulic radius would only account for 2 per cent. General formulae for

flow of water in open channels are discussed, it is shown that variations in velocity are such as to point to influence of new factor hitherto absent from hydraulic formulae. New formula, which includes a silt factor, is put forward for computing velocity of Nile River.—*N. J. Howard.*

Water Meters Increase Revenue. ANON. Can. Eng., 45: 15, Oct., 1923. Metering of water services in and around Montreal, Canada, producing satisfactory results. Metropolitan Commission will issue instructions that water services be metered in Pointe Aux Trembles, Laval, and Montreal East. In St. Laurent, previous deficiency in operation of water system, replaced by surplus of $7000 after metering.—*Norman J. Howard.*

Keeping our Water Fit to Drink. DR. FRANK HALE. Scientific American. November, 1923. Résumé of steps taken to control New York City water supply. Three laboratories maintained and microscopic examination carried out daily. During 1922, 4177 microscopic examinations made. Reservoirs with top and bottom draft examined at top and bottom. Generally speaking, microscopic examination serves to identify source of water. Contamination of well supply may be indicated by presence of microscopic organisms. Taste and odors may be caused by 22 species. Asterionella produces aromatic odor when present in 500 to 1000 standard units per 1 cc. With 1000 units present a geranium odor occurs. As the numbers increase up to several thousand per cc. the odor becomes fishy. This odor may also be caused by smaller quantities dying. Tabellaria and asterionella in small amounts may cause a distinctly earthy odor also produced by large amounts of synedra. Anabaena and aphanizomenon when present in 500 to 1000 units produce a faint grassy odor. Large numbers cause an odor of a pigpen character. Uroglena produces an oily, fishy taste and odor, first noticeable in probably 500 to 1000 units. In larger quantities it resembles cod liver oil. Synura may cause cucumber odor in amounts as little as 50 units. Water containing the dead organisms has an immediate first taste but no after taste. Microscopic organisms do not affect the health. Organisms will die if reservoir allowed to stand from three weeks to three months. Aeration and treatment with copper sulphate and chlorine employed for destruction of organisms. Copper sulphate in dosage ranging between 0.05 and 1.00 p.p.m. by weight was applied according to species present. Effect of copper sulphate treatment is shown by immediate intensification of distinctive odors, by reduction of number of organisms in water through sedimentation. Sometimes increase in water bacteria occurs. Cyanophyceae may produce scum after treatment, of varied colors, pale blue, yellow, red or brown. Copper sulphate applied in burlap bags, containing 50 lbs., dragged through the water in zig-zag courses. Launches were successfully used in the large reservoirs, treatments being applied over parallel courses 100 feet apart. In Kensico reservoir copper was applied by mechanical means; dry feed method was found very successful. At winter temperature, 0.2 p.p.m. killed asterionella, and, at spring temperature, 0.12 p.p.m. Trouble with synura was overcome by copper treatment plus super-chlorination. It was found that 0.6 to 0.75 p.p.m. of chlorine destroyed the taste, and, after 12 to 24 hours, chlorine could not be tasted.—*N. J. Howard.*

Pittsburg, California, Sued for Typhoid Cases. Bull. Calif. State Board Health, March, 1923; Pub. Works, 54: 197, 1923. (*Cf.* this J., 10: 1140) Court decision gave total of $32,821 in damages to citizens who contracted typhoid fever through failure of chlorinating plant to function on water supply.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Sealing Permeable Foundation of Dam into Grout. W. S. Lea. Contract Record, 1923; Eng. Contrg., 60: 548–50, 1923. Describes method employed on small dams in Quebec to seal foundations on rock without use of cut-off trench. —*Langdon Pearse.*

Filter Plant Operation at St. Louis. E. E. Wall. Ann. Rept. Water Commissioner, 1923. Eng. Contrg., 60: 550, 1923. During year ending April 1, 1923, on average, 112.3 m.g.d. were filtered; at cost of $4.01 per mil. gal. Washing of filters is at rate of 15 gal. per sq. ft. per min. 1.409 per cent of water was used.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

New Water Rate in Saint Paul. J. W. Routh. Pub. Works, 54: 156–7, 1923. In Jan. 1923 new rates went into effect on sliding scale of service charges plus even charge of 6 cents per 100 cu. ft. Details are given. About 70 per cent of supply is metered.—*Langdon Pearse.*

Concrete Lining of Irrigation Canals and Laterals. R. C. E. Webber. Reclamation Record; Eng. Contrg., 60: 539–41, 1923. Cost and economic advantages are cited. With concrete, maintenance is lower and seepage is reduced.—*Landgon Pearse.*

The Bloomington, Ind. Water Supply Problem. Paul Hansen. Indiana San. & W. S. Assn., 1923; Mun. Cty. Eng., 64: 95–100, 1923. Details history, from first supply to present improvement, describing geologic conditions which determined final selection of site of dam and reservoir. Owing to failure of early works, serious water shortage resulted.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Constructing Earth Dams in Vermont. Pub. Works, 54: 80–2, 1923. Two dams, one 200 ft. high, were built for the N. E. Power Co., with cores of fine material deposited by hydraulic method between embankments of earth brought in dump cars.—*Langdon Pearse.*

Delaware River for New York Water Supply. Pub. Works, 54: 87–8, 1923. (*Cf.* this J., 10: 1144) New York City is seeking additional supplies for use after 1935.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Chlorination at Delaware, Ohio. Pub. Works, 54: 88–9, 1923. In spite of continuous use of Cl at high rate (1 to 2 p.p.m.), epidemic of enteritis occurred at Delaware, Ohio. Pollution entering river above intake is a factor.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Water Proofing on Reinforced Concrete Standpipe. G. C. Brehm. Ann. Rept. Dept. Pub. Works, Waltham, Mass., 1922; Pub. Works, **54**: 167–8, 1923. Eng. Contrg., **60**: 523–5, 1923. A 16 yr. old concrete standpipe, 100 feet diam, 43 feet high, was water-proofed by drying walls, mopping with asphalt, applying coat of felt, then mopping again, for five successive layers, outside being 6 oz. saturated duck; all mopped with asphalt; covered with 4-inches brick core built up in 6 feet sections. Cost was $16,500.—*Langdon Pearse.*

Repumping vs. Increased Pressures for Fires. Arthur Jensen. Can. Sec. Am. W. W. Assn., 1923; Eng. Contrg., **60**: 526–9, 1923, Can. Engr., **44**: 534–6, 1923. Motor pumpers or fire apparatus are more economical; 80 per cent of water works do not increase pressure for fires.—*Langdon Pearse.*

Boiler Plant Operation at St. Louis with Fuel Oil. E. E. Wall. Ann. Rept. Water Commissioner, St. Louis, Mo., 1923. Eng. Contrg., **60**: 525, 1923. Oil burned cost $0.5263 per 1000 pounds stream, as compared with coal cost of $0.2999; oil was used owing to coal shortage.—*Langdon Pearse.*

Comparison of Lead, Leadite, and Cement Joints. E. E. Wall. Ann. Rep. Water Commissioner, St. Louis, Mo., 1923, Eng. Contrg. **60**: 529, 1923. Cement and leadite are better insulators and stand more deflection. Lead and leadite joints can be made at any time. Cement joints are at a disadvantage in winter —*Langdon Pearse.*

Deflection Measurements on Arch Dam in Switzerland. F. A. Noetzli. Schweizerische Bauzeitung, Jan 20, 1923; Eng. Contrg., **60**: 530–3, 1923. Describes methods of measurement and calculations of deflection of arch dam in Switzerland on River Reuss, 75 feet high, with a 95.5 chord.—*Langdon Pearse.*

Chicago Diversion Now Paid For. R. I. Randolph. Can. Engr., **45**: 315, 1923. Discusses certain claims of Sir Adam Beck with relation to Chicago diversion.—*Langdon Pearse.*

Chicago Drainage Canal. R. I. Randolph. Can. Engr., **45**: 317–8, 1923. Discusses article by Holgate, and cites history of canal to show publicity in past covering 10,000 c.f.s.—*Langdon Pearse.*

Improving Wilmington's (N. C.) Water Supply. C. W. Smedberg. Pub. Works, **54**: 277–81, 1923. Changes and enlargement of filter plant, relocation of intake, and installation of motor-driven pumping plant, furnish better water at a saving in cost which pays for improvement. Details of intake pipe, submarine connection, and remodelling, are given.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Cleaning Water Mains in Manhattan, Kansas. B. L. Ulrich. Kansas Municipalities, June, 1923; Pub. Works, **54**: 281–2, 1923. Water has hardness of 450 p.p.m., and iron, 7 to 10 p.p.m. 7.8 miles of pipe were cleaned at cost of 11.6 cents per foot. Cleaning machine was drawn through by cable.—*Langdon Pearse.*

Benton Harbor Purification Plant. PEARSE, GREELEY AND HANSEN. Pub. Works, **54**: 285 9, 1923. This 2 m.g.d. plant treats both river and well water carrying iron. Arrangement is made for overdosing part of water, but this has not proved advantageous. Dorr thickener is used for preliminary sedimentation (1 hour); followed by 8 hours in 2 basins. Return sludge from Dorr Clarifier aids sedimentation.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

The Hetch Hetchy Dam Completed. C. W. GEIGER. Pub. Works, **54**: 302–4, 1923. Eng. Contrg., **60**: 256–7, 1923. Summarizes salient features of structure; arch dam, 700 feet radius; height, 341 feet; cost, $5,500,000.—*Langdon Pearse.*

Water Purification at Columbus. C. P. HOOVER. Ann. Rep., 1922; Pub. Works, **54**: 305, 1923. Eng. Contrg., **59**: 1035–6, 1923. Effect of temperature on softening reaction discussed in connection with reaction time. Use of CO_2 for carbonating softened water is being tried, using various devices.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Water Wastes, Meters and Rates at Baltimore. V. B. SIEMS. Eng. Contrg., **60**: 261–70, 551–62, 1923. Describes water waste survey made of high, low, and middle services. Inspections and pitometer surveys were used, cutting down waste in four (4) districts in amounts varying from 825,000 to 2,000,000 g.p.d. This has benefited sewage treatment works. Consumption in Baltimore is increasing. Only 11.3 per cent metered. Average daily consumption is 125 gallon per cap., divided into: commercial and industrial, 34.6 gal.; public and municipal, 10 gal.; waste, 13 gal., and domestic, 67.4 gal. Metering program is outlined, with costs, rates, and comparisons in detail.—*Langdon Pearse.*

Preparation of Water for Filtration. F. A. DALLYN AND A. V. DELAPORTE. Can. Sect. Am. W. W. Assn.; Eng. Contrg., **60**: 271–4, 1923; Can. Engr., **44**: 474–6, (*Cf.* this J., **10**: 1138). Intake should not be subject to gross pollution. Use of pressure filters is permissible with suitable laboratory force, on Great Lakes water; but not on highly resistant water. Optimum condition of water is important. Sedimentation of at least 2 hours is advantageous. To remove excess CO_2, following use of $Al_2(SO_4)_3$, Na_2CO_3 may be used. In iron bearing waters, chemicals other than alum may be required.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

The Siphon Spillway on the O'Shaughnessy Dam. G. F. STICKNEY. Eng. Contrg., **60**: 574, 1923. Eighteen (18) siphons are provided with total capacity of 20,000 C. F. S.—*Langdon Pearse.*

Blasting Frozen Ground in Excavation for Dam Foundation. Reclamation Record, June 1923; Eng. Contrg., **60**: 578, 1923.—*Langdon Pearse.*

The New Well Water System of Camden, N. J. J. H. LONG. Eng. Contrg., **60**: 258–9, 1923. Four (4) wells, sunk in sand, yield about 6,500,000 gal. per 24 hours.—*Langdon Pearse.*

Locating Leaks in Underground Pipe Lines, with Geophone. H. A. Ward. Mechanical Engineering; Tech. Paper 277, U. S. Bureau of Mines; Eng. Contrg. **60**: 89, 1923.—*Sangdon Pearse.*

Comparison of Flood Control Measures. Harry Taylor. Am. Assn. Adv. Science, 1923; Eng. Contrg., **60**: 563-7, 1923.—*Langdon Pearse.*

Economics on Cleaning Irrigation Canals. C. L. Tucker. Reclamation Record, 1923; Eng. Contrg., **60**: 568-72, 1923.—*Langdon Pearse.*

Rapid Sand Filtration Plant Operation. W. D. Hatfield. Can. Sect. Am. W. W. Assn., 1923; Eng. Contrg., **60**: 74-6, 1923; Can. Engr., **44**: 539-40, 1923. Simple description; non-technical.—*Langdon Pearse.* (*Courtesy Chem. Abst.*

A Water Borne Typhoid Epidemic of Unusual Character. C. K. Blanchard. Pub. Health News (N. S.): Eng. Contrg., **60**: 81-2, 1923. At Franklin, N. J., outbreak was caused by contamination through leaky check valve on special fire service.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

Constructing Mitchell Dam. L. G. Warren. Pub. Works, **54**: 247-50, 1923. Describes construction of gravity concrete dam on Corsa River in Alabama: cofferdams built in wide, swift, stream, with stone-filled timber cribs, clay being deposited for water seal.—*Langdon Pearse.*

The Corrosion of Underground Structures. E. R. Shepard. Mun. Cty. Eng., **64**: 51-3, 1923.—*Langdon Pearse.* (*Courtesy Chem. Abst.*)

The Resuscitation of a Water Company. Farley Gannett. Mun. Cty. Eng., **64**: 72-6, 1923. Story of repairing leaky dam impounding water for small town supply.—*Langdon Pearse.*

Why Mt. Pleasant, Mich. paid $39,750 for a $15,000 Water Improvement. C. H. Peterson. Mun. Cty. Eng., **64**: 85-6, 1923.—*Langdon Pearse.*

Effect of Feed Water Heating on Plant Economy. G. G. Bell. Mechanical Eng., **45**: 7, 417, July, 1923. Studies of plant equipped with 30 K. W. units, clearly indicating advantages of bleeding main turbine, in plants either with, or without economizers.—*E. E. Bankson.*

Concrete Pipe Plain and Reinforced. Jos. S. Lambie. Engineers' Society of Western Penna., **38**: 10, 471, January, 1923. Proper methods of testing pipe and description of "Machine Made" concrete pipe wihh numerous discussions and questions.—*E. E. Bankson.*

Design of Earth Dams. Joel D. Justin. Proceedings Amer. Soc. C. E., **49**: 5, 856, May, 1923. Practical criteria for design of earth dams. Design should be such that:—(1) Spillway capacity is so great that there is no danger of over-topping; (2) Line of saturation is well within down-stream toe, and also

well below surface of original ground below dam; (3) Up-stream and down-stream slopes are such that with materials used in construction, they will be stable under all conditions; (4) There is no opportunity for free passage of water from up-stream to down-stream face; (5) Water which passes through and under dam, has, when it rises to surface below toe, velocity so small that it is incapable of moving any of material of which dam or its foundation is composed; (6) Freeboard is such that there is no danger of overtopping by wave action. Factors affecting position of line of saturation are given in detail; also movement of under-ground water, and its relation to design of earth dams. An equation is developed which will determine position and slope of line of saturation in dam and a variety of actual problems are worked out. Each criterion is thoroughly discussed and explained; for example, slope for up-stream face of dam should generally be determined by angle of repose of material when under water, being made flatter than that indicated by experiments as safe, and in general, not steeper than half that at which same material would stand out of water. Slope of down-stream face should be flatter than angle of response of material. Many protection methods are well discussed. Freeboard must include allowance for maximum height of floods. .For greatest "Flood Flows" see transactions A. S. C. E., **77**: 564 1914. Table of statistics given, for 120 successful earth dams, from 25 to 240 ft. in height. To be safe, any earth dam must meet each and all of these criteria. **Discussion.** J. E. Fields, J. C. Stevens, and J. D. Austin. Ibid. **49**: 9, 1874. November, 1923. Valuable discussion on original paper, including additional data. Table on failures and partial failures of earth dams; curves and table to find volume of earth dams for various heights and slopes; table of maximum recorded floods in American rivers.—*E. E. Bankson.*

Tentative Plan for the Construction of a 780-Foot Rock Filled Dam on the Colorado River at Lees Ferry, Arizona-Discussion. C. A. LaRue. Proceedings Amer. Soc. C. E., **49**: 5, 942, May, 1923. Results of detailed survey, are compared with preliminary estimates in original paper, with comments on discussion by other members.—*E. E. Bankson.*

Improved Type of Multiple-Arch Dams. Fred A. Noetzli. Proceedings Amer. Soc. C. E., **49**: 6, 1065, August, 1923. Describes multiple-arch dam of improved type, in which each buttress pier consists of double walls stiffened by cross walls. No multiple-arch dam has ever failed. It is essential that foundation of a multiple-arch dam be impervious by nature, or be made so by grouting. Full theory of design is given, and cases cited. A well designed multiple-arch dam, with double wall buttresses, may be built economically to height of 200 ft. and more; is structure, the stability and safety of which are beyond doubt. Danger of up-lift is practically eliminated. The multiple-arch dam involves less excavation than gravity type, less time for construction, less hazard from floods during construction; can be built with architectural appearance that affords beauty with impression of strength.—*E. E. Bankson.*

Stresses in Multiple-Arch Dams. B. F. Jakobsen. Proceedings Amer. Soc. C. E., **49**: 6, 1093, August, 1923. Complete discussion of stresses in multi-

ple-arch dams, with full theory and examples. Writer concludes that stresses should be determined with greater precision than in the past; and that higher dams can be built safely, and high stresses can be used.—*E. E. Bankson.*

Chlorine Control (for Water Purification, etc.) Apparatus for. J. W. van Meter. E. P. 199,052, 12. 12. 21. Chem. & Ind., **42**: 854A, Sept. 7, 1923. Apparatus comprises dome-shaped body, fitted to closed transparent vessel below in which is supported graduated inverted funnel. Lower vessel is filled with liquid (e. g., paraffin, if dry chlorine is required; or water, if chlorine water is to be supplied). Chlorine enters funnel from above, depressing liquid to a predetermined level, and escapes from port in side of funnel, passing through liquid in outer vessel in bubbles which can be regulated. To deliver chlorine water, the paraffin is replaced by water, which is sprayed into the upper dome continuously. Flow of gas is regulated as before. (A. G. P.).—*A. M. Buswell.*

Deaeration and Degasifying of Water and Other Liquids. D. B. Morison. E. P. 199, 748, 23.12.21 and 4.4, 14.6, and 14.7, 22. Chem. & Ind., **42**: 855A, Sept. 7, 1923. In physical process for deoxidising and degasifying liquids, more especially boiler-feed water, continuously flowing body of water, during its passage through deaerating chamber or chambers, is repeatedly raised to, and maintained at, boiling temperature, at any desired absolute pressure, by means of steam jets or nozzles provided at different points in line of flow. Arrangements are provided for discharge of gases evolved. The water is passed through condenser before being admitted to deaerator vessels, which are each provided with means for controlling pressure therein. Between the different vessels drop in temperature of water is caused by coil or the like. Provision is also made for interchange of heat between discharged and incoming water. Suitable valves allow for deaerators or degasifiers to be maintained under vacuum, but at different absolute temperatures (E. M. V.).—*A. M. Buswell.*

Rapid Gasometric Method of Estimating Dissolved Oxygen and Nitrogen in Water. H. G. Becker and W. E. Abbott. Sci. Proc. Roy. Dublin Soc., **17**: 249–253, 1923. Chem. & Ind., **42**: 1041A, Nov. 2, 1923. Air dissolved in water is set free by dissolving in the water a highly soluble substance; potassium hydroxide has been found the most effective. Water to be tested is saturated in bulb with potassium hydroxide and air set free is collected and measured. Oxygen is then absorbed in alkaline pyrogallol and residual nitrogen measured. Method is rapid and requires only 20–30 cc. of water. Total air found is slightly higher than by other methods, due to air in potassium hydroxide; whilst oxygen found is slightly lower, owing to incomplete absorption. Method has only been tested with distilled water, but should be applicable to natural or polluted waters (E. H. R.).—*A. M. Buswell.*

Treatment of Peat for the Softening of Water. G. G. Hepburn. E. P. 197,851, 20.6.22. Addition to 173,255 (J. 1922, 193A). Chem. & Ind., **42**: 854A, Sept. 7, 1923. When peat which is to be used for softening of water is

treated with alkali to remove soluble matter, and to produce insoluble alkali salts in peat, it increases very largely in bulk, when immersed in water; but if peat is washed and dried before being immersed this bulking does not take place. (J. H. J.)—*A. M. Buswell.*

Micro-sampling for the Determination of Dissolved Oxygen. R. V. Allison and J. W. Shive. Soil Sc., **15**: 489–491, 1923. Chem. & Ind., **42**: 1042A, Nov. 2, 1923. Modified Winkler apparatus is described for sampling of liquid media in which dissolved oxygen is to be estimated (G. W. R.).—*A. M. Buswell.*

Method of Water Purification. W. F. Langelier. U. S. P., 1,465, 137, 14.8.23. Appl., 25.2.20. Chem. & Ind., **42**: 1042A., Nov. 2, 1923. In usual method of water or sewage purification by addition of soluble aluminum salt to coagulate suspended matter, coagulation and sedimentation are hastened and amount of aluminum salt required is much reduced if small quantity of an acid, such as sulphuric acid, or an acid salt, such as sodium bisulphate, be simultaneously added.—*A. M. Buswell.*

Irregularities in the Rate of Solution of Oxygen by Water. H. G. Becker and E. F. Pearson. Sci. Proc. Roy. Dublin Soc., **17**: 197–200, 1923. Chem. & Ind., **42**: 1042A, Nov. 2, 1923. Rate of solution of oxygen at surface of still water under constant conditions follows same logarithmic law as if water were being constantly mixed, up to point where water is 60–70 per cent saturated. Beyond this point rate of absorption is irregular (E. H. R.).—*A. M. Buswell.*

Report on Trade Refuse (Coal Trade) in the West Riding. H. MacLean Wilson. Reprint. In discharges from 85 collieries today there is danger of stream pollution. In 65 of these there are coal washers; in 45, a chemical plant. In many cases there is danger from blowing off boilers, water softening, and escapes of oil. Pollution by coal washing water has been comparatively easy to deal with; effective settlement generally produces an innocuous effluent; but quantity of sediment produced is so large that constant care is needed to keep settling tanks clean and effective. Recently, in several cases, colliery owners have been persuaded, with good results, to use automatic and mechanical means for separating and removing sediment. Pollution by chemical discharges, such as waste waters from recovery of ammonia, extraction and purification of benzol, etc., which, it will be noted, are processes new in connection with collieries since 1896, is not so easy a matter to deal with, and has at times caused the Board great trouble. Three methods have been found useful in preventing this pollution. In 20 cases, chemical refuse is used up for quenching coke; in 12, it is disposed of by irrigation upon a spoil bank generally burning; and at 8 collieries, it is discharged into old pit workings. In one case, it is mixed with water used for coal washing, and in one case it is discharged into the public sewer.—*A. M. Buswell.*

Water Works Plant at Woodbridge, Ontario. W. B. Redfern. Can. Eng., **44**: 21, 520, May 22, 1923. Supply obtained from open well, 50 feet from Humber River. At 14 feet depth water filters through bed of sand into a

well. 100,000 gallon standpipe when full gives town pressure of 55 lb. per sq. in. Water for fire can be drawn from well and standpipe simultaneously.—*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

Report of Committee on Water Supply and Water Purification. Public Health Bulletin 133, U. S. Public Health Service, May 1923. Recommends endorsement of proposed amendment prohibiting discharge of polluting material from vessels while in vicinity of public water supplies; suggests consideration of amendment concerning use of watertight storage containers; regulation concerning quality and handling of ice effective until July 1, 1924, is advised. —*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

Hydrogen Ion Concentration of Natural Waters in Relation to Disease. W. R. G. Atkins. Journal State Medicine, **31**: 5, 223, May 1923. With exception of bog waters and waters abnormally rich in metallic salts, naturally occurring water are at pH favorable to continued existence of Vibrio Cholerae and typhoid bacilli. Suggestion made that water be made safe by making as alkaline as pH 10.5 by addition of ash from vegetable matter rich in carbonates of potassium and sodium.—*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

Purification of Drinking Water in the Field. Lt. Col. J. A. Anderson. Jour. Royal Army Medical Corps, **40**: 6, 401, June 1923. Standard British Army purification method is addition of alum (5 g.p.g.) formation of aluminium hydroxide and its removal by sedimentation or filtration through sand or fabric. Sterilization by addition of one part per million of free chlorine, contact 20 to 30 minutes and dechlorination as required by sulfur dioxide, sodium thiosulfate or sodium sulfite. Purification by iodine, acidification and use of tablets described.—*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

Report of the Committee on Limitation and Control of Chlorination of Water. Trans. 3d Annual Conference State Sanitary Engineers, U. S. Public Health Service Bulletin 133: 19, May, 1923. Report is an argumentative defense of chlorination for sterilization, stating that it is commonly an irregular, haphazard treatment, little understood and poorly controlled.—*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

Rules and Regulations for Swimming Pools. Jour. American Association for Promoting Hygiene and Public Baths, **5**: 61, 1923. Complete rules and regulations for swimming pools and bathing places as adopted by Arkansas, Louisiana, New Mexico, West Virginia, Idaho, Tennessee, Virginia and Washington State Departments of Health.—*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

Report of Conference on Phenol Wastes. U. S. Public Health Service, 11 pages. 1923. Phenol waste problem in United States discussed. Closed disposal system for treating coke wastes by evaporation most promising. Motion passed requesting U. S. Public Health Service to investigate problem from standpoint of public health, and Bureau of Mines to look into economic side of question.—*A. W. Blohm.* (*Courtesy Pub. Health. Eng. Abst.*)

Meter Installations and Meter Rates. E. I. Roberts. Pamphlet by Ohio State Department of Health. 1923. Increased cost in operation of water works brought about study of Ohio cities and villages with metered and unmetered supplies. Study indicates average daily consumption of 90 gallons per capita for 100 per cent metered services and 170 gallons per capita for unmetered services. Table and charts show per capita consumption and water rates.—*A. W. Blohm.*

A Study of the Effect of Gentian Violet on the Viability of Some Water-Borne Bacteria. Esther Wagner Stearn. Am. Jour. Public Health, 13: 7, 567, July 1923. Results of using broth containing gentian violet as inhibiting agent in comparison with other media for determining B. Coli in drinking water. Conclusion: does not inhibit vigorous growth of B. Coli or other important lactose fermenting water-borne bacteria.—*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

Suppression of Corrosion by Removal of Gases. Bulletin (French) issued by Union Thermique, 19 Boulevard Malesherbes, Paris. Corrosion of metals by water containing oxygen and removal of oxygen by passing through deactivating tanks containing specially prepared iron arranged in beds through which water must pass several times.—*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

The Post Swimming Pool. Major James C. Magee. M. C. Military Surgeon, 52: 5, 524, May, 1923. Army Pools regulated to avoid unnecessary pollution of water. Chlorine commonly used for disinfection, dose of 0.5. p.p.m. being maintained.—*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

Flow in California Streams. Bulletin No. 5, Appendix "A" to Report to Legislature of 1923 on Water Resources of California, Department of Public Works, Sacramento, California, 1923. Report contains 175 tables and 185 plates on precipitation, run-off, probable frequency of flood discharge, and storage developments.—*A. W. Blohm.* (*Courtesy Pub. Health. Eng. Abst.*)

Water Resources of California. Bulletin No. 4, Department of Public Works, Sacramento, California, 1923. Run-off from principal streams of state and comprehensive plan to obtain maximum service. Utilization and development of water resources discussed.—*A. W. Blohm.* (*Courtesy Pub. Health Eng. Abst.*)

The Emergency Treatment of Water for Drinking Purposes. A. P. Hitchens The Military Surgeon, 51: 657, 1922. Work of L. T. Fairhall and C. B. Wood, on treatment of water in Lyster bags, is reviewed, and procedure suggested, based on observation that, in test for free chlorine, change from lemon yellow color to orange occurs within surprisingly narrow limits. With 0.75 cc. of standard o-tolidin, threshold is very close to 1 p.p.m. chlorine. the recommended excess. Within limits, the smaller the amount of reagent added, the deeper the color produced with same concentration of chlorine. Emergency treatment of water with iodine (J. J. Hinman. Univ. of Iowa Monographs.

Studies in Medicine, Aug., 1918) is outlined. Five cubic centimeters standard tincture (7 per cent) in a Lyster bagful, 1 drop per quart, will render even raw Potomac River water safe for drinking in 30 min. As in case of chlorine, excess iodine may be removed by addition of 1 gram sodium thiosulfate.—*R. E. Thompson.*

Storage Yards of the Detroit Water Department. C. P. McGrath. Amer. City, 29: 226–30, 1923. Description of the four service yards maintained: for pipe, specials, valves, and maintenance material. Methods of handling breaks, taps, and meters given. Special equipment, such as unloading cranes, motorized valve operating truck, trailers for tools, etc., are described. Department maintains repair shop for 78 automobiles. Detroit has over 160,000 meters in service; of which, last year, 6400 were repaired, and 47,500 tested; while 700 new meters were set.—*W. Donaldson.*

The Economics of Sewage Disposal. H. Burdett Cleveland. Amer. City, 29: 235–6, 1923. Capital investment in sewage treatment works should be governed by actual need, rather than by desire for complete purification, which may not be justified by benefits to be gained.—*W. Donaldson.*

From Red Ink to Profits. John Oliphant. Amer. City, 29: 237–8, 1923. Galva, Ill., by replacing steam equipment with oil engine for its well supply, and improvements to air lift, has converted monthly deficit of $300 to $500 to profit of $500 to $600, in spite of rate reduction of 15 per cent. Cost and efficiency figures given.—*W. Donaldson.*

Pure Drinking Water in New York State. Editorial. Amer. City, 29: 238. 1923. According to Division of Sanitation of New York State Department of Health, 9,182,000 of the 10,651,000 people who live in State of New York are now supplied with drinking water from public water supplies, and 7,796,000 drink water that has been sterilized.—*W. Donaldson.*

Constant Vigilance Reduces Water Waste in Ottawa, Canada. H. D. Hoolihan. Amer. City, 29: 258, 1923. Water-waste durvey made in 1912–13, cost $10,300.00. Subsequent survey of distribution system with pitometer photo recorder has been carried on by force consisting of one foreman and six men with three house-service inspectors to follow up defective plumbing. Since 1919, 764 leaks in services and mains have been stopped, with estimated saving of 8 to 10 mgd. (Imp). Per capita consumption has decreased from 189 in 1913 to 173 gallons (Imp) in 1923. Present population supplied with water is 116,205, consumption is 21 mdg. (Imp.), with 10 per cent metered.—*W. Donaldson.*

What is the Index of Stream Pollution? Anon. Amer. City, 29: 264, 1923. Comment on recent bulletin of U. S. Public Health Service regarding self-purification of the Ohio River, discussing relation of plankton and other aquatic life to stream pollution.—*W. Donaldson.*

Types of Meter Rates. ANON. Amer. City, **29**: 270, 1923. Tabulation by Detroit Water Department classifies meter rates used by American Cities as follows: (a) Uniform Minimum Rate, which entitles user to stated quantity; (b) Service Charge, made in addition to charge for water; (c) Graduated Minimum Rate, in which minimum increases with size of meter; (d) Sliding Scale, with or without minimum rate, or service charge. Majority American Cities use sliding scale with minimum charge, N. E. Water Wks. Assn. recommends minimum service charge.—*W. Donaldson.*

Convert Water Waste into Profit. C. C. BEHNEY. Amer. City, **29**: 274, 1923. Assumes that 15–50 per cent of total pumpage is preventable waste, due to, (a) Underground leakage, (b) Fixture leakage, (c) Wanton waste, and (d) Underregistration of meters. As results of surveys, Hagerstown, Md., pop. 29,000, daily consumption 4.1 mg., 75 per cent metered, reduced a per capita consumption of 141 gals., to 120; and Lexington, Ky., pop. 45,000, 100 per cent metered, per capita consumption 100 gpd., found 0.7 mgd. leakage, repair of which brought per capita consumption to 82 gpd., of which 42 gpd. was industrial.—*W. Donaldson.*

Will It Pay to Burn Oil Instead of Coal? W. F. SCHAPHORST. Amer. City, **29**: 375–6, 1923. Presenting a graphic solution to the problems.—*W. Donaldson.*

The New Well Supply of Waupaca, Wisconsin. W. G. KIRCHOFFER. Amer. City, **29**: 460–3, 1923. Unsatisfactory surface supply has been replaced by shallow ground water gotten in unique way, sinking cylindrical concrete caisson, or collecting well, 37.5 ft. deep, 30 ft. inside diameter, and 18 in. thick, by excavating inside with a clam-shell bucket. Bottom of caisson was constructed with cutting edge of concrete to make a hole 8 ft. larger in diameter than itself, this space being filled with gravel as the sinking progressed, forming a strainer against entry of sand. Six ports, 5 ft x 3 ft. pierce the concrete cylinder to allow entrance of ground water, openings being covered with porous screen, 6 in. thick, of grouted gravel. Yield of collecting well is estimated at 700 gpm. Cost was $11,200.00.—*W. Donaldson.*

Oxyacetylene Welding in Artesian Well Work. ANON. Amer. City, **29**: 499–500, 1923. (Reprint from "Oxy-Acetylene Tips.") Methods of welding 18 in. and 24 in. steel well casing are described.—*W. Donaldson.*

Filtration and Chlorine versus Typhoid Fever. CHARLES STREITHOF. Amer. City, **29**: 507–8, 1923. Traces development of the water works at Evansville, Ind., from first installation, in 1871, to present time. Detailed figures show decline in typhoid incidence with increasing use of city water, and improvements in water purification and general sanitation. In 1908, with 41 per cent of population served, and no water purification, there were 213 cases of typhoid; in 1922, with 95 per cent population served with filtered and chlorinated water, there were only 7.8 cases per 100,000.—*W. Donaldson.*

Modern Equipment Augments an Old Municipal Water-Supply. C. W. Melcher. Amer. City, 29: 585–6, 1923. (Reprint from Compressed Air Magazine.) Prior to 1916, the spring supply of Elmhurst, Ill., was distributed through wooden mains installed in 1886. Drilled wells, 975 ft. and 1400 ft. deep, are the present source. Improvements made by municipality, since taking over works from private company in 1920, include complete cast iron distribution system and new power-house with oil engines for driving air compressors, pumps, and generators. Water is pumped from wells by air lift into surface reservoir, then repumped with centrifugals into distribution system and elevated tank. Combined capacity of the two wells is 1250 gpm. Replacement of deep well pump in 975 ft. well by air lift increased yield from 185 to 630 gpm. Main power unit is a type PO oil engine of 73 B. H. P. Fuel cost of raising water from wells and delivering to mains against 43 lbs. pressure is 0.87 cents per 1000 gals. with oil at 5½ cents per gallon.—*W. Donaldson.*

The Water Works of Elyria, Ohio. Anon. Amer. City, 29: 587–91, 1923. Illustrated description; particularly of improvements installed in 1920–23. Supply taken from Lake Erie through wooden crib and 1500 ft. of 24 in. pipe. Low-lift steam turbine driven centrifugals deliver to 8.0 mgd. purification plant, consisting of (a) baffled mixing chamber of 20 minute retention period; (b) twin coagulating basins, each 39 × 196 ft. × 16 ft. deep, with retention of 4.5 hours; (c) four filter units of 2.0 mgd. capacity each; and (d) covered clear water storage of 1.0 mg. capacity. Crank and fly-wheel pump delivers filtered water to city. Interesting features are boiler plant equipment, dry feed machines (3) for lime and iron, or lime and alum, float valve control on coagulating basin inlet, arrangement of the ten basin sludge valves, Venturi tubes on basin inlets to proportion flow, master filter effluent control operated by level in clear basin, in addition to individual filter control. Elyria distribution system embraces 65.4 miles of 4 in. to 20 in. pipe. Value of works as of Dec. 1920 was $2,000,000, one-half of which is represented by distribution system. Revenue from water during 1922 was 17.4 cents per 1000 gallons.—*W. Donaldson.*

A Million Dollar Water Supply for a City of 18,000. Cora Moore Cameron. Amer. City, 29: 598–9, 1923. Inadequacy of small impounded supply and unsuitability of local ground water led to development of new supply by damming Pine Creek, installing new pumps, filters, and 0.5 mg. elevated tank in city. Dam is 3125 ft. long and 30 ft. high, with reinforced concrete spillway 200 ft. long. Catchment area is 48 sq. mi.; reservoir holds 4 billion gallons and submerges 1300 acres.—*W. Donaldson.*

Water Supply Conditions in Jerusalem. Anon. Amer. City, 29: 608–9, 1923. Acute water shortage reported, due to growing population. Present supply is rain water, caught in cisterns in city, supplemented by water from a cavern 13 miles south of city at head of Wadi Biarfi. Tunnels through the rock bring the spring water to storage in the three Pools of Solomon, ten miles south of city. Much repair work has been done recently to clear tunnels of debris and put two of storage reservoirs in condition. Work on third pool

is deferred. Combined capacity of the three pools will be 40 mg., equal to three months' supply for whole city.—*W. Donaldson.*

For Shorter Spacing of Fire Hydrants. WILLIAM R. CONARD. Amer. City, 29: 643–5, 1923. Writer favors spacing hydrants at 100-foot intervals, instead of average 500 ft. in vogue. Presents comparative figures to show advantage, from standpoint of capital investment, of shorter spacing, which saves large outlays for hose and fire engines, besides giving better fire-fighting facilities.—*W. Donaldson.*

Sanitary Problems of Growing Villages. GEORGE C. WHIPPLE. Amer. City, 29: 400–1, 1923. Four transition stages in water supply and sewage arrangements are outlined as follows: (a) primitive rural, (b) advanced rural, (c) primitive urban, and (d) advanced urban. In the last stage, public water supply and public sewers replace cruder facilities. Simple sketches illustrate the text.—*W. Donaldson.*

Design, Operation and Accomplishments of the Stream-Line Filter. GEORGE W. FULLER. Chem. and Met. Eng., 29: 1006, 1923. Stream-line filter is invention of H. S. Hele-Shaw; is made of pack of specially prepared paper, impervious to water and oil, and roughened to provide passageways; pack is held within a container, between two press-heads. At one press-head are channels through which influent is led to each of the openings of larger diameter, and at other press-head are channels connecting with smaller holes to remove effluent. Effluent, even under heavy pressure, can pass from larger tubular openings only between laminae of heavily compacted paper, with stream line flow, into smaller tubular openings which form exit from filter. It is essential that material used have rough surface, so as to provide passageways. Passing certain mixed liquids through filter several times, with increasing pressure on pack each time, different substances are removed at each filtration. Some of the accomplishments are: removal of color from water; production of clear and nearly tasteless fluid from milk; extraction of oil from feed water; and reduction of dilute activated sludge to 60 per cent water content.—*John R. Baylis.*

Edge Filtration. Chem. and Met. Eng., 29: 932, 1923. Principle upon which this device operates, is called edge filtration; is invention of Dr. Hele-Shaw. Liquid being filtered does not pass through porous filtering medium, but, in thin films, between laminae of material. A paper that has slight matt to its surface is used, so that, no matter how tightly the sheets are pressed together mechanically, minute passages for liquid remain. Sheets have two sizes of holes; influent liquid, entering larger ones, passes between the sheets, and out through smaller ones. It is rather a clarifier, than filter proper. Several figures, showing details of filter, are given.—*John R. Baylis.*

The Use of Aluminum to Prevent Steel Corrosion. ARTHUR V. FARR. Chem. and Met. Eng., 29: 1188, 1923. Aluminum alloy surface is produced by heating material in reducing atmosphere containing finely divided aluminum. Mate-

rials so treated have the advantage of their original structural strength unimpaired, together with corrosion resistance of aluminum. Aluminum is less active chemically than zinc; hence this treatment should offer better protection to metals than sherardizing.—*John R. Baylis.*

Flow of Fluids—How Electric Motors Should be Applied to Pumping Equipment. R. H. Rogers. Chem. and Met. Eng., **29**: 928–31, 1923. Selection of motors for most successful operation under all conditions and circumstances is not a simple problem. A desirable characteristic in centrifugal pumps is that of having load fall off each way from best operating point. This prevents overload coming on motor, either by an accident, or by mishandling of valves. Centrifugal pumps are rated at their best operating point; any deviation in speed, head, or delivery, will result in higher cost per unit duty. Operating at lower than rated head should be avoided if possible. For constant speed service, either induction motors of squirrel-cage type, or synchronous motors, may be used. When direct current is used, the shunt-wound motor is not well adapted to centrifugal pump drive: a compound motor should be used with only a moderate series field. For adjustable speed pump drives, wound-rotor motors, or brush shifting, commutator type may be used. Squirrel-cage motors can be used on centrifugal pumps up to 500 h.p. Synchronous motors are not usually installed below 75 h.p. Reciprocating pumps, rotary pumps, and screw pumps, have heavy starting duty; and squirrel-cage motors cannot be used, if line disturbance is objectionable. Squirrel-cage motors are controlled by manual or automatic compensators. Automatic compensator may be actuated by push button, float switch, thermostat, or by diaphragm pressure switch. Wound-rotor motors for constant speed are controlled by automatic panel actuated by push button, float switch, or the like. Synchronous motors are usually controlled by compensator and field discharge switch.—*John R. Baylis.*

Internal Treatment of Boiler Water—Proper and Improper. D. K. French. Ind. Eng. Chem., **15**: 12, 1239, Dec. 1923. Enormous amount of data, experience, and even *imagination*, called for. It is possible, by correctly applying small amount of material inside, to produce an effect which would require many times that quantity, if added outside. Organic compounds, which retard precipitation in the cold, are found to aid it at the high pressure and temperature in boiler. *Scale Formation.* With calculated concentration of organic matter in boiler, crystalline separation can be prevented. While sludge may be objectionable, its removal is much easier. Economy in softening chemicals is possible, if balance between them and controlling organic matter is properly adjusted. Organic matter, properly applied, may render crystalline deposits amenable to slow removal without discontinuing boiler operation. Certain inorganic chemicals, sodium silicate being best example, may produce same effect when conditions indicate addition of organic matter as undesirable. Silicate of soda is frequently sold as boiler compound. Used alone, its efficiency is low. Its reaction is little understood. Sellers claim that it treats the metal, not the water: this claim has been proven to be untrue. *Corrosion.* Concentration of soluble salts causing electrolytic action, CO_2 and

oxygen, are most common corroding agents. Inorganic chemicals seem not to have any effect on dissolved oxygen. CO_2 can be removed by lime. Organic acid compounds tend to retard caustic embrittlement by alkaline water. Corrosive gases, especially oxygen, are absorbed; and electrolytic corrosion, reduced. Alkaline tannates, applied to waters of low alkalinity, produce similar results. Chromates and dichromates are frequently used where organic matter cannot be applied. Composition of boiler water, after varying periods of operation, when using organic treatment, cannot be even approximated volumetrically. Organic matter interferes with ionization. *Foaming.* A problem, almost purely, of surface tension. Outside treatment offers nothing to control. Soluble inorganic salts and some organic compounds toughen surface film and thereby increase foaming. A combination of these is most serious; and suspended matter, in addition, will raise water level to dangerous degree. Incomplete precipitation of carbonates of lime and magnesia may cause serious foaming. Organic internal treatment will sometimes definitely retard foaming. In contrast with other oils, castor oil may, under proper conditions, markedly control foaming. By combining precipitation outside with proper anti-foam treatment inside, even the poorest water may be used with fair satisfaction. *Boiler Compoumds.* Attention is called to compounds of undesirable types, and to methods used to advertise them. So-called "metal treatment" types consist almost invariably of sodium silicate solution sometimes colored with dyes. They have been tried and emphatically condemned by the U. S. Government. The insoluble type of boiler compound consists, practically always, of tri-calcium phosphate, talc, aluminum phosphate or some similar compound. Only true benefit derived from their usage is production of more bulky and less crystalline deposit. Soluble compounds in solid form include tri-sodium phosphate, soda ash, or mixtures of these with tannin, etc. *Graphite.* Being electropositive to iron, causes solution of the metal without being itself affected. "Graphite is a scale remover for same reason that hydrochloric acid is. That is, it corrodes metal under scale and frees scale from metallic surfaces." (Jour. Soc. Naval Engrs., 1911.) The same article classifies graphite as a "Dangerous Compound."—*Linn H. Enslow.*

Determination of Carbon Dioxide in Mineral Waters, etc. J. Cannizzaro. Ind. Eng. Chem., **15**: 10, 1074, October, 1923. Rapid and accurate determinations of CO_2 content of highly charged waters, beverages, etc., may be made by following procedure. Sample is kept chilled in ice, to avoid loss of CO_2 when opening bottle. To measured quantity of standard Na_2CO_3 solution, free of bicarbonates, add measured portion of sample, and mix gently. With standard acid, titrate, using phenolphthalein, and methyl orange indicators, thus determining residual Na_2CO_3, and that converted by CO_2 present to $NaHCO_3$. (Above method in general may be applied to collection of water samples of high CO_2 content in cases where CO_2 cannot be titrated at sampling point. The Na_2CO_3 solution should be free of $NaHCO_3$, or else amount present pre-determined. Separate sample of 200 ± cc. is collected for CO_2 determination. With each sample bottle, send small slender vial containing known quantity of standard Na_2CO_3 solution. Fill sample bottle almost full; remove vial stopper, and drop both stopper and vial into sample. Mix sample and

Na_2CO_3 solution by gently inverting a few times after replacing stopper of sample bottle. Sample is now ready for shipment to laboratory. Large excess Na_2CO_3 is undesirable. A good grade of flint-glass sample and reagent bottles must be used.—ABSTR.)—*L. H. Enslow.*

Effect of Deaeration of Natural Waters on the Carbonate Equilibrium. D. H. JACKSON AND J. R. MCDERMET. Ind. Eng. Chem., **15**: 9, 958, Sept., 1923. Following results observed during operation of spray-cascade type of commercial de-aerator operating in vacuum and handling water at 140°F. or higher. Carbon dioxide was completely removed. Bicarbonates were partially decomposed, percentage of decomposition varying directly as content of raw water: average 35 per cent. Result was water of high pH value, containing from 10.5 to 15.5 p.p.m. $CaCO_3$. Most of the calcium originally present in the 35 per cent decomposed bicarbonates, precipitates. Hydrogen Ion Concentration was lowered from pH 6.85 (and less) to pH 8.8 to 9.5. Observed pH values, obtained colorimetrically, were in fair agreement with theoretical, as obtained from formula $H^+ = 6 \times 10^{-11} \times \frac{\text{Bicarbonate } CO_2}{\text{Carbonate } CO_2}$, where H^+ = hydrogen ion concentration and respective CO_2 values are in parts per million.—*Linn H. Enslow.*

Preliminary Examination of Water Samples. W. D. COLLINS, AND MARGARET D. FOSTER. Ind. Eng. Chem., **15**: 10, 1078, Oct., 1923. Rapid turbidimetric estimation of calcium and sulfate in water described, using, respectively, acid potassium-oxalate and acid barium-chloride. Reliability of total hardness as determined by soap method (A. P. H. A. Standard Methods) is shown by comparison with that calculated from gravimetric determinations of magnesium and calcium. Average difference between calculated and soap-determined, for 174 samples, is 8 per cent of calculated. Soap results tend to be low for hardness less than 50 p.p.m. Methods for calcium and sulfate follow. *Sulfate.* Prepare standards to contain 5 to 35 p.p.m. SO_4. Place 10 cc. portions of standards and 10 cc. sample of water in test tubes (100 x 10 mm.). To each tube add 1 cc. reagent (100 gms. $BaCl_2.2H_2O$ + 48 cc. HCl, Sp. G. 1.19, in 1 liter dist. water). Shake all tubes vigorously and compare turbidities. Samples containing more than 35 p.p.m. SO_4 should be suitably diluted. *Calcium.* Prepare standards from 4 to 24 p.p.m. Ca^{++}. Place 10 cc. portions of standards and water sample in test tubes. To each add 1 cc. acetic acid (equal vols. 99 per cent acid and water). Shake thoroughly. Add 1 cc. potassium-oxalate solution (20 gms. $K_2C_2O_4$ in 100 cc. water). Shake thoroughly again. After 10 minutes, turbidities may be compared. Relative turbidities are fairly constant for 3 or 4 hours. Dilute suitably when more than 24 p.p.m. Ca^{++} present. *Accuracy of Methods.* 77 samples examined for $SO_4^{=}$ varied from gravimetric results by only 2.5 p.p.m. $SO_4^{=}$ where 10 cc. sample could be used. 0.5 cc. samples, containing from 350 to 750 p.p.m. $SO_4^{=}$, diluted to 10 cc., gave 50 p.p.m. error. 68 samples examined for Ca^{++}, where 10 cc. sample could be used gave average error of 2.2. p.p.m. Above methods are only applicable as preliminary or field determinations, and are not intended to replace gravimetric analysis.—*Linn H. Enslow.*

Determination of Dissolved Oxygen in Presence of Iron Salts. A. M. Buswell and W. W. Gallaher. Ind. Eng. Chem., 15: 11, 1186, November, 1923. Winkler method, as modified by Rideal and Stewart, and adopted by A. P. H. A. as Standard, is dependent upon oxidation of a manganous salt in alkaline medium by dissolved oxygen present. Upon acidification, the manganic compound is again reduced and liberates free iodine quantitatively. Ferric iron will, if present, also liberate free iodine in acid solution. Theoretically, each p.p.m. Fe would make the result for oxygen 0.14 p.p.m. too high; but, in practice, error is found to vary between 0.10 and 0.13 p.p.m., thereby invalidating the method when much iron is present. Mohr's method depends upon oxidation of ferrous iron by dissolved oxygen in alkaline medium. In presence of iron, the Levy modification of this method, as improved by Letts and Blake, gave accurate results; whereas the modified Winkler method did not. Valuable review of the literature is given, and bibliography of 21 titles is appended. —*Linn H. Enslow.*

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